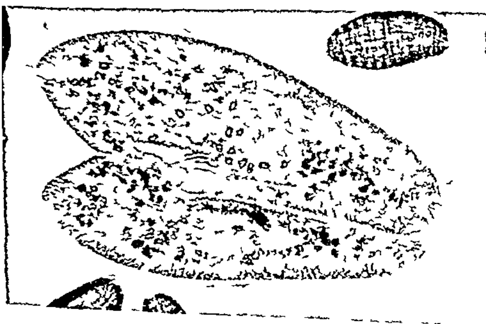
McGraw-Hill Encyclopedia of Science and Technology

of Science and Technology

AN INTERNATIONAL REFERENCE WORK

IN FIFTEEN VOLUMES INCLUDING AN INDEX

VOLUME 7 IBE LYT



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Suggestions to the Readers

Earth sciences
Earth tides
Earthmover
Earthquake

Mercury (element)
Mercury (planet)
Mercury battery

Circuit electronic
Circuit breaker

Animal virus
Animal feed composition

(LEFT) Photom c og aph of glass c ystals (*B eau of Standards*) (RIGHT) *Pa amecum caudat m* I conju gat on (*photograph by R V shn ac*)

L brary of Congr Cat l Card Nu ber 60 11000

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Ibex

Th wild goat f the Old W ld *C p a ib x* fo nd in th high ky mo nta n u regi n of Asia No th Afri a nd Eu pe It i mewhat mo e tock ly b lt a d ho ter legged than the chamo s (s e CHAMOIS) B th e e ha l ng hea y urv g horns wh ch m y reach a l ngth of 56 in on a ld b ck The mal m y w gh a much a 200 lb the d e s m wh t l ghte

Th e ar umbe of elated spec e n Sib r a the H mal y mo nta A abi a d Aby i i all f wh h a e s ught by hu te s both f r food and fo t phy h ads *S e* ARTIODACTYL Go T

[J D B]

Ibis

A n me ppl d to erta n lo g l gged he nlike b d b lo g ng t th fam l s Ci o d a d Thr k orn th dae furthe h ra t i ed by d wn c rved b lls d h ghly gr gar s h b ts. Th ood ib *My t meric* f th outh rn Co t l Pla n f the Un ted State t rk be l ng g t the f m ly Ci o i dae nd d st n g h d f m ll t ue h by the l k of fe thers n t h d ft a terrest i l feed r

Th tr b e f ed r ne h ll w w te n both l d a d m habitat e t ng fi h s f g n k d cr tace n They n t in olo-



Th wh e-f ed gl y b *Pl g d h h* f gth t 26 in (F m E L P im F ldb k f N t l H st ry McG -H ll 1949)

ni s omet mes n very l rge number in cypres d other swamp tree Two spe ies are thern found p imar ly in Fl rida the ar the white bi *E do mus alb s* nd the European gl sy ibi *Pl gadis falci ellus* The white fa ed gl y ibi *P chihi* occurs fr m O egon outhward into T xas nd M xic The last two pe ie are br n c l d th thers white *See* CICO IIFOR IFS

[J D B]

Ice cream

A food p ep d f m a frozen m xt r of m lk p oducts a d fl ring made mooth by t rring during fr ezing Comm rc al ice cream ar es in c mp s ti dependi g larg ly on tate law The us al fat c ntent is 10–14% and the nonfat milk ol d a e ag bout 10 5% Sweet e s is s pplied by c e or beet suga (ucr e) t the amo i t f 15% Thi is supplemented with c rn ar (dextr e) nd rn i up To prot ct ice cr am ag i st heat h cks duri g ma ket ng 0 2–0 4% f lloidal m ter al su h s gel t n or egetable g m i added a ll a 0 1–0 2% of an em l fie ch as m no r diglyce ide

Ice cream manufacture C mmercial ice cream i always mad from p te ri d a d h mogen d mi Both batch and continu u fre er are u ed U lly the hold ng sy tem (68 3–71 1 C for 0 m n) f p t urizat on is empl yed lth gh h gh tempe atu e hort t me tre tments that m ke possible t o s flow w e b g u d by me of th la g r pl nts by 1958 In u ing uch m th ds t mp tu as h gh s 110 C with a f w se nd h ld t m a e u d The h gher t mperatu es p e p t t e gl of th whey protei t f d a he r body i the m and a mooth textu e in th i e m w th ut d maging the del te fla o f the m lk p od cts

At fi t the f eez g wa done i bat h machi e b t c nt n us fr ezing ha alm st nti ely r pl c d the l m th d Th o tin u p r t n i m ffi ient and p odu e n i e cr am with a m th r text a d b dy Cont nuo s fr e e s v ry n c pac ty fr m 85 to 300 gal per h u N m o s fla o e added t ice r am Th m t c mm s v lla Ch l t tr wb rry b tter pec n p h e ff d dy l o are p pular

D r g the f ezi g pr s a r s inc porat d t tl c e m mix Th is term d e r n A 100% err n me ns th t the ol m of the m x h b e do bl d the w ght pe un t lume h be hal ed Som t t lim t th max mum

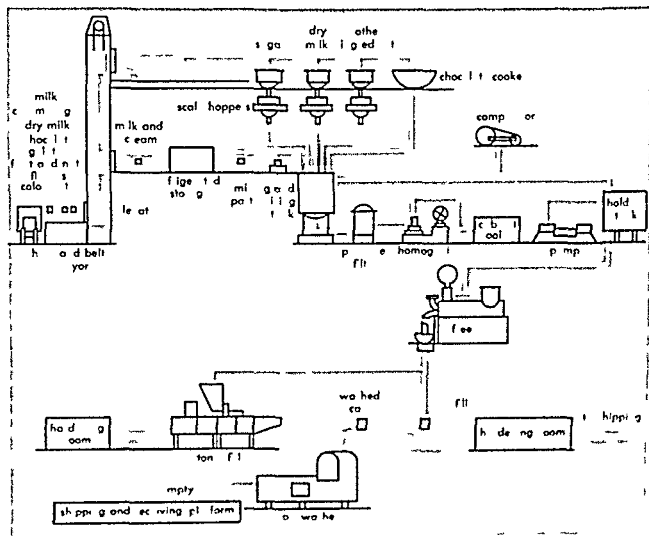
overrun to 100%; other places a legal minimum on the weight of the milk solids contained in a unit volume of the ice cream. Ice cream is hardened by passing it through freezing tunnels or by placing it in low temperature (−28.9 C) rooms where the air is usually circulated to facilitate heat transfer.

During World War II the shortage of milk fat led to the consideration of vegetable oils in the manufacture of frozen desserts. The oils commonly used are cottonseed, coconut, and soybean. The use of these oils for this purpose is illegal in some states, but others permit their use if the frozen product is properly labeled. Manufacturers in Texas, a leading state in the use of vegetable oils in frozen desserts, coined the name Mellorine for such products. There are certain economic advantages in the use of vegetable oils in place of milk fat.

Ice milk In the period prior to World War II considerable interest was shown by consumers in a low-fat frozen product which came to be called ice milk. The product varies in fat content from 3-6% in nonfat milk solids from 11-14%, and in sugar from 12-15%. It is sold either hard in the same manner as ice cream or soft directly from the freezer. The lower fat and higher protein content of ice milk appeals to the diet-conscious consumer, and the relatively lower price is an added feature. [P.H.T.]

ICE CREAM MICROBIOLOGY

Sources of microorganisms The cream, condensed and dry milk products, egg products, sugar, stabilizer, flavoring and coloring materials, and fruits and nuts used as ingredients in ice cream may be contaminated with microorganisms. Therefore the ice cream mix must be pasteurized before freezing because a low temperature in itself is not sufficient to kill microorganisms. Other possible sources of microorganisms are equipment and utensils used in manufacture, scoops and dippers, vendors, employees, and air. Stringent regulations must be established for all manipulation of ice cream from producer to consumer in order to avoid recontamination, especially with regard to pathogens. Once incorporated, microorganisms will survive a long time in ice cream. This can be seen



Flow sheet of ice cream manufacture. (From Food Industries, S. C. Prescott and B. E. Proctor, Food Technology, McGraw-Hill, 1937)

Tabl 1 P rsl t ce of Salmon lla typhosa (Bact n m typhos m) 1 1 e tre m

T m ft f ee g f tak g sampl d y	Typh d ba t a ×10 pe ml
F esl ly fro	51 000
5	10 000
0	0
104	900
165	610
60	7
31	1
544	13
y rs	6

M J Pru l nd J M B V b l ty f *Bac le um t pho m* cr m *J B t iol* 11 " "9 1) 6

fr m the d t of M J P ucha a d J M Bra non n *T ble 1 (ab dged)*

Kinds of microorganisms A wide a ety of m c oorg m el d g t ept co ci mi rococci (rm *ba te* a p *r form s* yea ts nd mold *may be f) nd* N l ti n of pecie by fr ez ng *take pla e* N g owth and only l w de tru tion f m c oo g m t the final p d t w ll occ r Th ef the fl f i eam c n ts of rgan m rv g p teu zat n ncorpor ted by *ntam n t* With ell c ntr ll d an tat o d ting y od t plat c u t may be s low as a f w th u and with a les method they may b i th m ll ns N rm lly a sl ght ner a f th ba te al e t t k s pl c dur ng m n fa tur espe lly fte homo en ati n a d fr ez ng due t th b ki g up f lumps f bacte a (ee Tabl 2) A pl te co nt l low 100 000 per m ll l ter g rally r ga ded s cc ptabl f om th a tary po t f i w

Hygienic measures Th ese include pr per pas t u zat n of th m x nd ad q at sanit zing of q pment P st ur zat n mu t be m re int s e th th m than w th milk b e ncrea d m lk f d p t t m roo ga m to ome degree Ab t 68 C f r 30 min r 79 C f 25 ec re ap pl ed t obt ffi nt m rg of af ty f thi w y all pathogen a k lled and tot l b ct ial unts of 10 000 o l p gr m u ally a hed If ghe ounts fte pa t u zat on re d t th m d o gan m Th ourc f the e rg n m adeq ately cle ed fa m r plant equ p t S t zi g f q pm t i a h eved by

T bl 2 Effect of ious st p i m uf cture on t d rd pl t ou t of Ic m

S f m f	U perv sed preparat (1 m es)	S pe sed p p ratu (11 m es)
Bef re pa t n	10 8 566	4 617 53
Bef re homoge t	10 748	11 8 0
Af homogeni t	00 4	18 643
Bef n g	89 311	31 381
Af g	3 4 300	33
Af f ee g	4 83	58 136
Af h ed	390,–	39 1 7

N E Olson, n l A C. E y Th ba t n l co t s f ice cre m repo t f perim ts ba t n l co trol commerci l pl ts, J Da ry Sc 8 415 19

clean ng and ste ilizing operation with l eat r chem cals

Bacteriological control For determining hygi enic quality of ice cream the laboratory tests used are s milar to th se empl yed for m lk (*see* MILK) Of these the standard plate count and the te t for col form bacteria have f und w despread applica ti n *See* MICROBIOLOGICAL METHODS

[J W P]

Bibl og aphy G D Turnb w P H Tracy ar d L A Raffett *The Ice Cr am Industry* 2d ed 1947

Ice field (Eisstromnetz)

A network of interconnected glaciers or ice stream w th c mmon s urce area or areas, in con t a t to ice heets and ice caps The German word E sst omnetz tr n lates l terally to ice stream net The term generally is used for *glacial sy t ms* of moderate size (such as le s than 3000 m les) a d s mo t applicable t m untainous regi n Be ng ge erally as ociated with terrane of substantial rel ef ce-field gla i rs are m stly of the b oad b s n cirqu and mountain alley type Thus dif fe nt ectio s of an ic field are often eparated by linear ra ge b dro k ridges and nu ataks

Contrast with ice sheet An ic heet is a broad akelike glaci l ma with a relati ely flat surfa e d gentle el f I e she ts are not confined r c ntroll d by all y top g aphy and they u ually c er bt d t p g aphic feat res such as a conti nental pl teau (f r exampl much of the Antarc tic ic h et) or a lowla d p lar a ch pelago (uch s th Gr nla d ce sheet) Although generally e h et are of e y larg dimen on in some re g o s m ll rather flat c bodie ha e been called i e she ts be a e they ar th nned remnants of *nce la ge mas es of th i f m* Small ice sheets nd e en e field ar m tim s i cor ectly re ferr d t l y castal r lay ob rver a i ap ven th ugh thei c nfigur tio s h e been well h ract riz d

Contrast with ice cap Ice c p are prop ly de fin d a d *mel ke gl c al mas* u ually at h gh el vati They may for example compr the c m al n u hm t ar a f an ice field at the crest of m unta n ra ge o they may st in olated po t ons as sepa ate gla ial n is *n thems l es* Th latter type s haract i ed by a d t nctly *on* v umm t d m bord d by *tiguous gla* i l *l* pes with relat ely reg lar ma g s not d sse ted by mll r alleys abutm nt r dges

Similarities and gradations Th e are all g a d t betw n t e c p i fields a d sh *eets* O e a p od f t me morphogenet g *adat* al eque may also d l p n a y ne region Ma j i heet fo mple pr bably *origin* t f m the th k n ng a d xpans n f e feld a d *th* al s n e of bo der ng p edm nt gl iers C n e ly ic fields can d elop thr gh the *th n* i g nd etr ct on of a larg i e h *t o erly ng* m ta ou t r n S GLACIATED TERRANE GLACIER

[M M M]

o errun t) 100% other places a legal minimum on the weight of the milk solids contained in a unit volume of the ice cream. Ice cream is hardened by passing it through freezing tunnels or by placing it in low temperature (−?8.9 C) rooms where the air is usually circulated to facilitate heat transfer.

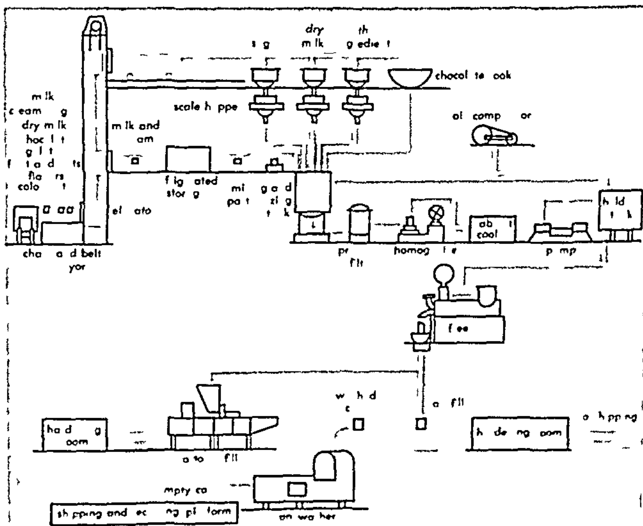
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[R H T]

ICE CREAM MICROBIOLOGY

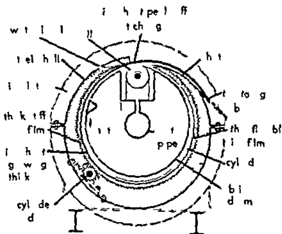
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Flow sheet of ice cream manufacture. (From Food Industries; S. C. Prescott and B. E. Proctor, Food Technology, McGraw-Hill, 1937)

g e te t on m imp tan i th m nuf t r f at r i e f u e in ref ger to ars fi hing bo ts, fi h and m at p cking plants a d da ri Th N t nal Asso i tion I Ic I dustr es r p rted th U.S i e p od ction i 19 7 s 23 950.550 t (alued at $223,268 067) ompared to 3 233 966 t in 1953 Bulk ce p d tio has been f lling ff t the r t of almo t 2 000 000 t n a y ar a mechanical ef ige at n mak s fu tl r i o d n i e ma k ts The dome tic ic market practi ally hed w th devel pment f th a t m t c h i e hold efr g r t r

M st c s m d in galvan zed that a e p rt ally imme ed b n n an ice-m k ng t k (F g 1) B i e mad f sod m chl r de or c l m hlo id i ed Th b ine s c oled by am m i a the efri er t e ap t in p pe oils or bri coole s bmerged n th ce ta k The ce s filled with raw wate t e ted w t r f it in t lly c nta s larg m t f mpur t e Th w t r is u lly p ec led C ld l i e c lates d the ice a s t f e e th wat Com m r l i e s f o n n 300- r 400-lb blo ks f r whi h the f ee ng t m with b i t 12 F i from 38 t 4 h ur F eezing t me dep nds larg ly n the th k e of th i ake a d tl brine t mper tu e In l g pla t n e arr nged g oup f mes f h rve t g s ma y 34 a at t m A trav l ng cr ne p k p a f zen gr up t ns- po t nd dr p t t d p t nk f r thaw g then m es t t dump wh e th e cakes sl de o t d i t t ge oom Th empty c n are filled w th fresh wate d a e et rned to the ce t nk by th r e



Fg 2 C mm l fl k m h

If lear i e is r qui d tl e w t r in each can m t be agit ted w th a dur ng fre zing th r wi e paque i fo med B ca i the wate m t be o led to 32 F bef re fr ez ng can start nd b ca e of syst m lo ab t 1 6 tons of refrigera t is r qu e t mak 1 ton of i e wh n th raw water ent rs at 0 F

The m nufact re f i e n l i h flake or cub f m by o t nu us ic m ke s (Fig 2) has taken er la g p rti n f the comm i l m rket in r ent ye r Al o mall f lly aut m t c elf con ti ned cube and fl ke ic m kers h s b en de l oped f u e i st r nt h tel clubs and h s p tal

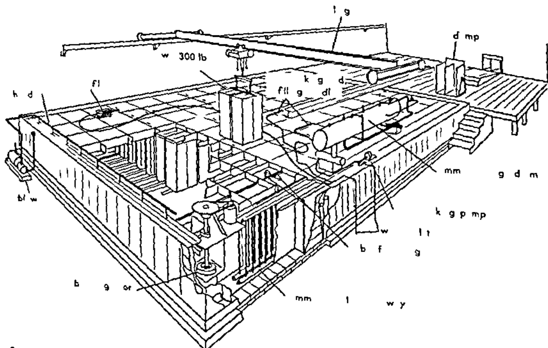


Fig 1 Typ l i pl t (W rth gt P mp d M h e y C p)

f

Ice island

Ma i e l odies of fl ating ice in the Arctic O ean fr m 100 t 200 ft thick irregular in hape and from a few quare mile to 300 quare miles in area Ice i lan l originate in the lan l fa t ice al ng the high latitude northern h res of the Canadian archipelago and Greenland The unbroken appearance of the i land i in great contra t to the ur r unding pack ice which normally almo t c m pletely cover the Arctic O ean and which attain a maximum thickness of only 20 ft It wa the un l r ken appearance and the ele ati n of i e i land above the pack ice that fir t attracted the attention of the crew of U S Air Force weather reconnai ance planes in 1946 (Fig 1) Since that time over 80 ice i land have been ol erved all l ut a half d zen or o l eing in the numer u l ay and trait f th Canadian archipelago

Character and formation Ice i land are characterized l y (1) al ence of pre ure ridge uch a are f und on the pack ice (2) long hall w drainage chann l mo t evident in summer when they are filled with meltwater and (3) the presence of du t and dirt layer in the ice as well a occa ional rock on the urface and remnant of plant and animal material which testify to clo e proximity to land at me time

An ice helf (a floating l ody of land fa t ice) 60 miles l y 10 mile in iz i l ocated l etween McClintock and Markham Bay on Northern Ellesmere I land It ha l een quite exten ively tudied and ha l een f und to l e imilar in all re pect to the ice i land In Augu t 1947 an aerial ph t graph wa ol tained f the e tern en l f thi helf with a large piece f i e nearl y which had l r ken fr m it Thi piece later moved out into the Arctic Ocean t bec me a fl ating i e i land Other large por ti n are mi ing fr m the helf since it wa fir t vi ited l y C S Nare in 18 5 and R E Peary in 1906

The i e i land pr l ably l reak fr m th helf during year of generally warm Arctic climate uch a the peri d 1900 1930 The age r period of growth of the land fa t ice along the e h re



Fig 1 U S Air Force photog ph of Ice Isla d T-3 (Off ial ph og aph USAF Camb idg R sea ch C n r Mass)

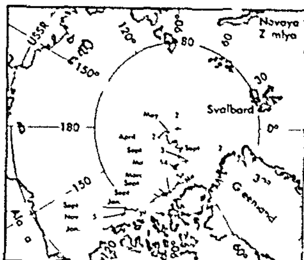


Fig 2 Dr ft of Fletcher s Ice Island T-3 du g its period of occ pancy (USAF Camb idg Research Ce ter Mass)

into ice a thick a the ice i land can l e mea ured in hundred of year and depend on the gen ral climatic c ndition

Scientific endeavor In March 19 a landing wa made on one of the e i lan l le ignated T 3 (T for radar target) or Fletcher Ice I lan l f r C I J O Flet her who wa in charge of th fir t operation there Thi i land wa occupied fr m March 195 t May 19 4 April 1955 t Septem ber 1955 and continually in e April 195 In 1952 a landing wa al ma le on T 1 the fir t i land di covered and largest of the kn wn ice i land l ut no permanent facilitie were in talled In 19 the USSR located ne of it N rth I le tati n on what i evidently on f the e i lan l

The ice i lan l are exc ll nt platf rm f r Arctic sci ntifc t lie Once away fr m the lan l ar a the i lan l are mo ed at speed up t miles per day l y the win l in an erratic c ur that take them lockwi e ar und the Ar ti l a i fr m Elle m re I lan l towar l the ea n rth f Ala ka an l ea tern Siberia an l fr m th re t war l th I I (Fig 2) Fr m thi area th y m y m e l y k t Elle mere f rming a circul r path f m 2000 or 3000 mile wh ch i co re l in al t 15 ye r or they may m e fr m th p lar area th t f the Ar ti O an l a in l way f th Greenland S a in whi h a th y w ll ntin th and ent ially l int grat Th amp at Fl t l r I I lan l i ed exten i ly f r Ar ti t l t m teor l g w an grapl y gra it geomagn t i n pl ri n l aur ra

I ll g aphy II Lan l berg (ed) 41 (ph s i I 3 1)4 I S K e g K R t r n awa M D nl r an l C Hatt r l y S ul Ar t i e i l n l Arcti f 10 1 2

Ice manufacture

C mm i l pr l ti n f arti i l i e fr m w t r dr i fr m th w l f at n f il n f t l (t Dry ice) l m l c l r fr g rat Ol

g t st nom c imp rtan e s the m nufa tu of w ter e f r u r f ig rat r car f hing boats, fi h and meat p ki pl ts a d da The N t nal A or ati n of I e Indu tries r p rt d th U.S p odu t n 1957 s 23 950.5 0 ton (l ed at $223 268 067) c mp ed to 32 233 966 to 1953 Bulk e pr duct ha been f lling ff t th rat of alm t 2 000 000 ton a y r as *mech* al r f ig r t makes f rther in ad n ice ma kets Th d mest ice ma ket p act ally r hed w th devel pment of the utomat c ho e-h ld ef g ator

Most c m de in gal a zed c n th t r part ally imm ed b e in an e-mak ng t nk (F g 1) Br ne mad f d um chlo ide al c m hl de s d The b ine cooled by m m s th r frig rant evap r t s p p l r bri e oolers l me ged n the c tank The c a a e filled w th aw wate o tre ted w t r f it t ally conta n l ge am u t of imp ities Th w t r s ally p eco led Cold br n e rcu lates und the to f eze the water Com mer l e f o e n 300- o 400-lb blo k for wh h th f eezing t m with b at 12 F s from 38 to 42 F ezi g t m depends l rgely n th thi k es of th ak nd the b e t mp r tu e I l g pl nt c n a rranged in g o p frame fo harv ti g ma y 34 an t t me A tra l g c n p ck p f group t ans-port a d d y it t d p ta k fo thaw g th m es t to an d mp wh e th e cake sl d t a d int t ag ro m Th mpty n a e r filled w th fr h wat and a e returned to th t k by the n

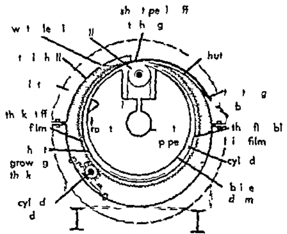


Fig 2 C mm l fl ke mo h e

If le r e is r qui ed th water in ea h c n must be agit ted w th a r during freezing ther wi e paq e is f rmed Be au th w ter m t l o led to 32 F b f re f eezing can start and b c u e of sy t m l es about 1 6 t s of refrigera t o require t make 1 ton of e wh n the raw wate e ters at 70 F

Th m factu f ic in l sh flake r cube form by nt nu u emaker (Fig 2) has taken e a l rg porti n f the mm rci l market recent ye r Al mall f lly t mat c elf-con ta ned ube nd flak emak rs ha e been de el oped fo u e n e taura ts hotels l bs nd hos p tal

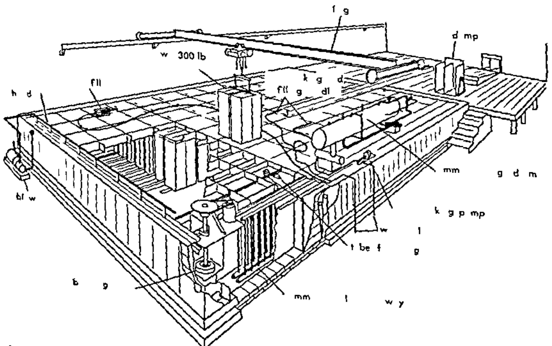


Fig 1 Typ l k pl (W rth gt P mp d M h ry C p)

Ice island

Massive bodies of floating ice in the Arctic Ocean from 100 to 200 ft thick, irregular in shape and from a few square miles to 300 square miles in area. Ice islands originate in the land-fast ice along the high-latitude northern shores of the Canadian archipelago and Greenland. The unbroken appearance of the islands is in great contrast to the surrounding pack ice which normally almost completely covers the Arctic Ocean and which attains a maximum thickness of only 20 ft. It was the unbroken appearance and the elevation of ice islands above the pack ice that first attracted the attention of the crews of U.S. Air Force weather reconnaissance planes in 1946 (Fig. 1). Since that time over 80 ice islands have been observed, all but a half dozen or so being in the numerous bays and straits of the Canadian archipelago.

Character and formation Ice islands are characterized by (1) absence of pressure ridges such as are found on the pack ice, (2) long, shallow drainage channels most evident in summer when they are filled with meltwater, and (3) the presence of dust and dirt layers in the ice as well as occasional rocks on the surface and remnants of plant and animal material which testify to close proximity to land at some time.

An ice shelf (a floating body of land-fast ice) 60 miles by 10 miles in size is located between McClintock and Markham Bays on Northern Ellesmere Island. It has been quite extensively studied and has been found to be similar in all respects to the ice islands. In August 1947 an aerial photograph was obtained of the eastern end of this shelf with a large piece of ice nearby which had broken from it. This piece later moved out into the Arctic Ocean to become a floating ice island. Other large portions are missing from the shelf since it was first visited by G. S. Nares in 1875 and R. E. Peary in 1906.

The ice islands probably break from the shelf during years of generally warm Arctic climate such as the period 1900–1930. The age or period of growth of the land-fast ice along these shores

Fig. 1 U.S. Air Force photograph of Ice Island T-3. (Official photograph USAF Cambridge Research Center, Moss)

Fig. 2 Drift of Fletcher's Ice Island T-3 during its period of occupancy. (USAF Cambridge Research Center, Moss)

into ice as thick as the ice islands can be measured in hundreds of years and depends on the general climatic conditions.

Scientific endeavor In March 1952 a landing was made on one of these islands, designated T-3 (T for radar target) or Fletcher's Ice Island for Col. J. O. Fletcher who was in charge of the first operation there. This island was occupied from March 1952 to May 1954, April 1955 to September 1955, and continually since April 195_. In 1952 a landing was also made on T-1, the first island discovered and largest of the known ice islands, but no permanent facilities were installed. In 1955 the USSR located one of its North Pole stations on what is evidently one of these islands.

The ice islands are excellent platforms for Arctic scientific studies. Once away from the land areas the islands are moved at speeds up to 5 miles per day by the winds in an erratic course that takes them clockwise around the Arctic Basin from Ellesmere Island toward the sea north of Alaska and eastern Siberia and from there toward the Pole (Fig. 2). From this area they may move back to Ellesmere, forming a circular path of some 2000 or 3000 miles which is covered in about 15 years, or they may move from the polar area south out of the Arctic Ocean basin by way of the Greenland Sea, in which case they would continue south and eventually disintegrate. The camp at Fletcher's Ice Island is used extensively for Arctic studies in meteorology, ocean graphy, gravity, geomagnetism, ... and ...

P II graph H. Land berg (ed.), *Ad a*
C ophysi v 1 3 195 I S K nig K R t er
aws M Dunbar and C Hatter I s Smith Ar t
c e l lan l A r c 5 6 10 19

Ice manufacture

Commercial production of artificial ice from water or dry ice from the solidification of carbon dioxide (see Dry ice) by mechanical refrigerat... Of

glac ı th J c b havn Gla er at l titude 68 N cal ng ab t 1400 berg yea ly and the large t ı th Humboldt Gl c r at lat t de 9 with a e ward fr nt e tend ng 65 mil s The emaind r of th Arct c be g er p ome fr m East Greenland a d the ı land eecap f Ellesm re I l nd Icel d Sp tzberg n, nd No a Zemly w th almo t n siz ble b rg p duced al ng the E r ıa or Ala ka Arct c oa t No ıc b rgs a d cha ged o d It ınto th N th P fic Oc n r ts adjacent as e c pt few small be gs ea h y a th t cal e from th pıedmo t glacı rs al ng the G lf of Al ka The e h e e no gn fic nt dr ft S e ARCTIC OCEAN ATLANTIC OCEAN

O ean u rents f the Ar t c and adjac nt as d t min th d ft d lımate d tribution of ceb rg d ha g l ttle ffe t ex ept on sm ll a l haped fr gm ts The dom na t d ft long th Ea t G e la d c a t thwa d ar d the tıp f G l nd and th n n thw rd al n the *t c t He e th drift ng b rgs ȷ ın the maın* body of West G ee l d b rg nd d ft ın a o n t r lockwı g) al ac s D vıs St a t and Baffi B y Th berg re th pt so thwa d al g the co t f Baffin I land Lab ado nd N wf nd land by the Lab ador C r t Th *drift term* t al g th Gr nd Ba ks of N wf ndland here th w te of the Lal ad r C rr t *mıx* th the w m Gulf St am nd e e th larg t of b rg melt th n t o t three week Fre k *ıcebe g* d ft h *v been r p ted wh e be gs r r m ng f agme t* were hted off Scotland N a Scotı B muda a d n the A s I la d Su h re p t h re ext m ly r e Ab t 400 berg e h y r a e c rr ed pa t Newfo ndland as



Fg 2 A ctc c b g 8 g has b d d t fo m v lley dry-dock typ Su h gr t q e sh p mm to th gl c olly p od c d ebe g f th N rth N t th b sh d sm ll floe f c s r d g th be g

s rvıvor of the tımated 3-year journ y fr m We t Gree land The emaınder b come strand d along A ctıc c ts d sh als and are ultımately de t yed by wave rost and mmer m lting

Iceb g *ın th* N rthern Hemı ph rarely reach propo tı ns l rger than 2000 ft ı breadth or 400 *ft ın heıght* bo e th water (F g 2) H w e er *tr e gl c* l ıce ı lands e al mıl s ın extent a e occ nally f und and ha e even erved a *flo t* ba e for scıent fic tudıes The *rıgın of these ra cou terpart* of the ommon Antarctıc *type ıs u ce t ı* but th ght t be an ıce h lf *al ng* northern Ellesmer Island *S* ICE ISLAND

Antarctic icebergs I the Southern Ocean bergs *or g nat* f om the giant ıce h lves all along th

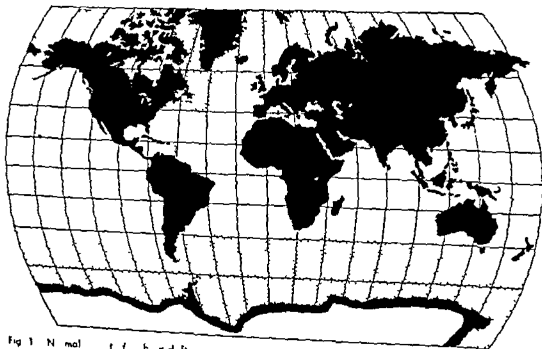


Fig 1 N mal t f b g d ft

Ice is also frozen artificially in a flat horizontal sheet for ice skating. Such skating rinks may be indoor or outdoor, permanent or portable. The rink floor is covered with pipe coils through which cold brine is circulated and over which water is sprayed until a frozen sheet 1/4–3/4 in. thick is obtained. The brine is cooled in brine coolers by a refrigerant such as ammonia or Freon 12. *See* REFRIGERATION.

[H M HF]

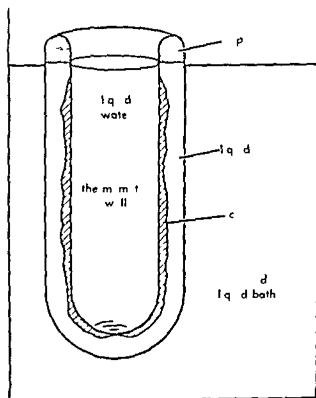
Bibliography: American Society of Heating, Refrigerating and Air Conditioning Engineers, ASRE *Air Conditioning and Refrigerating Data Book*, 1956–1959.

Ice point

The temperature at which liquid and solid water are in equilibrium under atmospheric pressure. The ice point is by far the most important fixed point for defining temperature scales and for calibrating thermometers (*see* TEMPERATURE). A closely related point is the triple point where liquid, solid, and gaseous water are in equilibrium. It is 0.01° higher on the Kelvin scale than the ice point (*see* TRIPLE POINT). The triple point has gained favor as the primary standard since it can be attained with great accuracy in a simple closed vessel isolated from the atmosphere. Readings are reproducible to about 0.0001 K, but dissolved gases or other foreign matter may raise the error to 0.001° or more.

The triple point apparatus shown in the figure consists of a thermometer well that is filled with liquid water and jacketed by a cavity containing the three phases of water under a pressure of about 0.006 atmosphere. The ice initially deposited by prechilling the well melts during the process of heat transfer from the thermometer. [R A BL]

Bibliography: H. C. Wolfe (ed.), *Temperature: Its Measurement and Control in Science and Industry*, vol. 2, 1955.



Arrangement for determining triple point.

Iceberg

A large mass of glacial ice broken off and drifted from parent glaciers or ice shelves along polar seas. Icebergs should be distinguished from polar pack ice which is sea ice, or frozen sea water, though rafted or hummocked fragments of the latter may resemble small bergs. *See* GLACIER; SEA ICE.

Characteristics and types. The continental or island icecaps of both Arctic and Antarctic regions produce icebergs where the icecaps extend to the sea in the form of glaciers or ice shelves. The "calving" of a large iceberg is one of nature's greatest spectacles if one considers that a Greenland berg may weigh over 1,000,000 tons and Antarctic bergs are many times larger. The glacial ice of which an iceberg consists is compressed snow having a variable specific gravity which averages about 0.89. This results in an above-water mass of from one-eighth to one-seventh of the entire mass. However, spires and peaks of an eroded or weathered berg will result in height to depth ratios of between 1–6 and 1–3. Tritium age experiments with melted Greenland berg ice indicate these bergs may be of the order of 50,000 years old. Minute air bubbles imprisoned in glacial ice impart to bergs a snow-white color and cause it to effervesce when immersed. *See* SEA WATER; TRITIUM.

Icebergs are classified by shape and size. The terms used are arched, blocky, dome, pinnacled, tabular, valley, and weathered for berg descriptions, and bergy bit and growler for berg fragments ranging smaller than cottage size above water. The life span of an iceberg may be indefinite while the berg remains in cold polar waters, eroding only slightly during summer months. But under the influence of ocean currents an iceberg that drifts into warmer water will disintegrate rapidly, its life being measured in weeks in sea temperatures between 40–50°F and in days in sea temperatures over 50°F. A notable feature of icebergs is their long and distant drift which may carry them into steamship tracks where they become hazards to navigation. The normal extent of iceberg drift is shown by the accompanying world chart (Fig. 1).

Arctic icebergs. In the Arctic icebergs originate chiefly from glaciers along Greenland coasts. It is estimated that a total of about 16,000 bergs are calved annually in the Northern Hemisphere, of which over 90% are of Greenland origin. But only about half of these are of a size or location to enable them to achieve any significant drift. The majority of the latter stem from some 20 glaciers along the west coast of Greenland between the 65th and 80th parallels of latitude. The most productive

Ichthyosauria

F h I ard th m t highly ad pt d f all r pt les to l fe in the sea W ll p ved f l h w th e t re body form th a e impre ions of tail fl k paddles d r al fin e n of bry c k l t s l ed up w th tl m thers body ready wh n b n t w m n the p n n the m ner of y u g wh les A p men h s b n rec red n hich b rth wa o rr ng t th t me f th m th r d th wh h h ws th t th eml ryo ere rot y ng hthyos u s wh h t had all wed fo f d

F rly hthy a r h d l g to thed fi h at h m ja imil r to the g p k a d gavial S m h d bl nt t th f cr h h ll fi I Lat Creta us form l t the teeth and had b k like tl o f th dfi hes and m rl s wh cl they g eatly e mbl d All we pred ceo s and m I rger n p b bl f d n th r i f thy u The arl est had t g fl t d te th t n sock ts L t r the socket ra t tl e int groo e and till l ter the t th be am mall and l elv t Th ey wa e pt all l rge t e k prey in mod r t ly deep w t

In a ly g n a the el ng te ta l wa turn d d w tow d tl e t p wh it w s pan f d i t n rr w el t fin Lat n th Jura i th ta l be m ho t d wa t n d abruptly d w at th t p f th t al upp rt f n la ged t m n l fi Thi t il fin wa th m i pr pul e rg n whi h tr n mitted t gre t f e th h th br ad fl t e t b a f tl h y p nal l mn V rt b r t 200 mb we e d l ped mu h s n h le

The pa d fi s o paddl d r d f om th fe t fl l t a d f tw ma typ br d d a r w u d a udd nd elevat de pr when th c t t th u fa t b e th o bme ged to f ed Th r wa al a t l l g d l fi without pp rt n kelet n wh les a d hark t p e t d l p whil w mm g Th tr t al with th enti ut l f th b d i p e rved th ma kabl f l f nd l nd tly at H lzmaden (m ny 60 ft Th gi nt f m of the Lat T i d E ly Ju a i the l rg t a m ls f th r day th l t p tat f th l ng t l d f m d w r pe ded by mall p b bly

A J c chthy sau m h ed d (S mpl fed f m E St m d by A S R m V rt b at P l f gy Th U ty f Ch g P ss 2d ed 1945)

m re act h rt ta led type T thless f rms late in the Cretaceo s r pidly decrea ed in numl er nd ext nction to k pl ce l ef re tl e cl e of the Creta eous wh n th ichthyo aurs w re evidently upplanted l y th mo a ur of the order Squa mata ubcla s Lep do u ia *See* LEPIDO AURIA SQUAMATA [C L CA]

Ichthyostegalia

A gr p f labyri th d nt mph bia found in Late Devon an depo t in Ea t Greenland and hence the old t r pr entati e f th class known at

d s l fi

co d l f

4 cm

T l of *I hthy st g o c t* ol l by th do t om ph bi h w ng fi ays et e f m f h o c to (*F m E H Colb rt E l to f the V rt b t W l y 1955*)

p e ent Th limb and g rdles ar of an amph bian p tt lth gh mall a d p i miti e in tru ture but th e i a defi it f edu ed caudal fin remi n ent of pi c ne ance tor Th *ertebr e a e* comparabl t tho e of cr pterygian fi he n th ne hand nd rha h t m us amph l an on th the The skull pp rs t b p cial d i g e ter d ct n of the oti notch than would l e exp t d in truly an tral amphibi n and the int rtemporal b ne i ab nt Th k ill is r mark l ly p im t ve th r f t r pa t c larly n the t t of a la ge canal f r the n t chord through th ba f the occipital reg on th s con tru t on ch r cte i ti of cro sopt ryg ans is ab se t n all lat r amphib ns *S e* AMPHIBIA FOS- SILS LABYRINTHODONTI RHACHITO II *see also* CROSSOPTERYGII [A S R]

Ictidosauria

A few extrem ly mammal l ke rept l (ub l s Synap d) ar gr up d nde the ord r Ictido- a ria S e tl l d d ge e a p obably temmed from mo e than a gl u e among l th de p b bly i phylogen ti ally rti a e techni lly exclud d by tl pt li n natu e of th l wer j w and m d lle e r R p nt ti e o c r n the upp rmo t T ia s c (probably l Low J r c) depo its On group the tritylo- d t s k own fr North Ame c A a E r pe nd South Afri Ict d aur p op r are known f m South Afr a ly All i tid au we e mall a imal o m r than 3 ft i length The g p i lud d both a n or a d h rb r and eem t h be n t ted to t re tr al l fe The re e t n of the s u es f mammal *S* SY APSI A THERAP IDA [E C O]

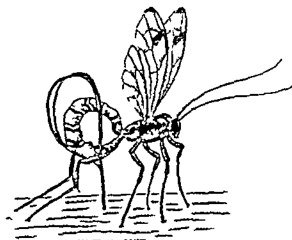


Fig 3 Antarctic iceberg Tabular type berg or ice island is common to all regions of the Antarctic seas Some of these bergs may reach over 100 miles in length The U S Coast Guard Icebreaker *Westwind* is shown in the foreground

Antarctic continent The e result in huge tabular bergs (Fig 3) or ice islands several hundred feet high and often over a hundred miles in length which frequent the entire waters of the Antarctic seas The most active iceberg producing region are the Ross and Filchener ice shelves in the Ross and Weddel seas The large size of these bergs and influence of the *Antarctic Circumpolar Current* give them an indeterminate life span When weathered Antarctic icebergs attain a deep bluish hue of great beauty rarely seen in the Arctic *See* ANTARCTIC OCEAN [R P DI]

Ichneumon

Any member of the insect family Ichneumonidae order Hymenoptera Although they are frequently called *ichneumon flies* these are actually wasps (*see* WASP) The ichneumons are a widely distributed and highly successful family There are over 6000 species in North America They are parasitic insects as larvae the female deposits her eggs within the body of the insect or spider host by means of her ovipositor which is frequently the most prominent part of her body The greatly developed ovipositor of some of the ichneumons as much as 6 in long on one species frequently causes people to be frightened by these harmless insects They are beneficial in helping control *very populations* of harmful insects Virtually every known species of insect is attacked by some species of ichneumon *See* HYMENOPTERA [J D B]



The l g ta l d th l a *Meg hy a l lo* (an ichneumon fly) le gth fem le to $1^3{}_4$ i (F om E L Palmer Fieldbook of Natu al H to y McGraw H ll 1949)

Ichthyopterygia

Predatory fish finned and sea swimming reptiles of the Mesozoic Era widely divergent from land forms although surely descended from some ancient terrestrial group as yet unrecognized All are much alike in body form short necked streamlined swordfishlike or porpoiselike in body yet unrelated to either fishes or porpoises a noteworthy example of convergence in evolution A single order is included in this subclass *See* ICHTHYOSAURIA [C L C]

Ichthyornis

A genus of fossil bird of Late Cretaceous age known from six species from the Niobrara formation of western Kansas and one species from similar beds in Texas These form the family Ichthyornithidae and with the related *Apatornis celer* (Marsh) family Apatornithidae the order Ichthyornithiformes (subclass Neornithes) They differ from all other birds except the Archaeornithes in having the centra of the dorsal vertebrae with each end concave (amphicoelous) *Ichthyornis* and *Apatornis* were pigeon sized flying birds with well developed wing and keeled breastbone When first described by O Marsh parts of jaws bearing teeth in sockets were associated with the other bones so *that for many years they were known as toothed* birds In 1952 however J T Gregory from studies of the original material in the Peabody Museum Yale University found that the jaw fragments were not a ian but were from reptilian mosasaurs See ARCHAEORNITHES AVES FOSSIL ICHTHYORNITHES NEORNITHES [A W]

Ichthyornithes

One of the thr ij ror l r comj i ing th il la Ne rnith e r true bird Tl tw famil f thi gr up w re until re ently pla l a an r l r Ichthyornithif rme in the ij er r l r O l nt gnatha in the belief that *I hthyo n ij* *t eth J T G r g ry howe l that th t thed jaw* l ng a igne l t *Ichthy rni* wa reptilia j l l ly that of a m a aur Thi rem d tl j rin ij l la i for j la ing *Ichthyornis* near th t tl l *H perornis* Howe er *Ichthy ni* l ff r fr n lat r bird in po ing bic n ave ertebra whi h t it apart at th i p r rdinal le l *The eight kn wn* specie of Ichthy rnith are all fr m tl Upj r Cretaceou f Kan a a l n rtl a tern T x They were flying bird l inlan l a ar l gull lik in tl eir pr porti n See AVE NEORNITHE [K C P]

gr wn rap dly but imperfectly to form keletal c y tals (F g 1)

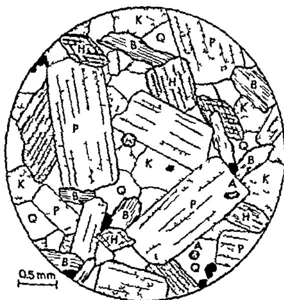
I mo t r ck grain shape i ont ll d largely by quence f m neral cry tall zat o and th na tu d ar ety f a sociated m rals A g ain s said t be euhedral f bound d f y its haracte i tic eryst l f es and nhedral f cry tal faces re ab- se t. Interm d ate forms ar ubhed al Cr tal developed e rly i a magma te d t be euhed al Late crystal h weve m et nterf ence f m n me o s adjace t gra ns and re for ed to a um rregular m tual bo nd r es

It i not nec s ary that all mutu lly int rfering g n de elop anhedral f rm S me min ral spe e po s a gr at r power f gr wtl (a gr ate form ene gy) and re capable f ma ntaining th r hara t ri t c ry tal form in c mpet t on w th d f ent m ne als

M t gneou r ks how a g ainy or granular te t re n whi h th maj rity f cry tal are oughly equ d men onal Ra ely g ains with e he- d l otl e d m nate and g e th rock an id o- m ph c gr ular t xtu e M r c mmonly n arly all g a n a e anhed al and the rock texture i allotri m rph gr nula M t r ks how an in t m diate o l yp d om phic g anul texture (F g 2)

Po phyriti te tu e The grai ze of s me gne- ou ock i extrem ly un form (eg granula tex tu e) but that of th r may be h ghl in qu g an ular Rock n wh ch rel t ly large cry tals (phe- nocry t) a e d sp rs d n a matri gr undma s of fin r g a ed gl s y m t r al a said t be porphy t r phyr c (F g 3) Po phy ti gla es th abu d nt ph n ry ts r k wn spec fi lly a it phy

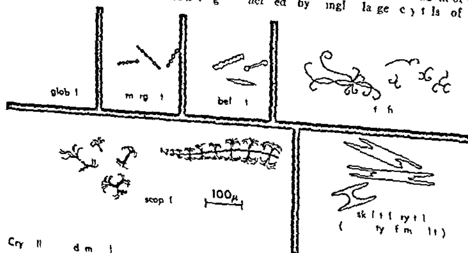
P rphyriti ock m y form in numb r f way (1) Phe ocry t m y h g wn arly and l wly hile the m gma was d ply f ur ed The gr und m may h ong led lat ft r th m gma w rupted t h ghe le l wh r aj d co li g d ( ) Ph cry t n many ocks (me g nt) m y de l p l te a d t ll atta n l g



Fg 2 Hyp d omorph c g l text e n g o od o t Euh d al pl g o la (P) ubh d al ho bl nd (H) b t te (B) hed l q tz (Q) and pot sh f ld pa (K) A s ry m ls i cl de h d l op t t (A) d bhed l m g t t (bla k)

d men on if the g owtl ate i s ffici ntly gr ter than that of adjacent mine al (3) Th e la g ry tal of s me plutonic ro k are p obably mo p op erly l ed as p rphyr bla ts They m y h e formed es e t lly in lid rock by recry tal lizat n a ded by re du l flu ds from the ol di fying magma (4) La ge cry tal in many rocks (c ta n p rphyri s and lamprophyres) may n t be ind genou They may h ve b en incorporated du ing intrus on f tl e magma (5) Ph no ry t m gl t d vel p by in culation or by di tu b nce f uper tu ted m gm S e LAMPROPHYRE PHENO- CRYST POR HYRY

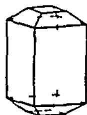
P kilit c t tu Th t ture nvol es numerous m ll g in f on m n ral i r nd m or ent tio ncl ed by ingl la ge c y t ls of anoth r

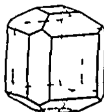


Fg 1 Cry ll d m l

Idocrase

A orosilicate mineral of complex compo ition crystallizing in the tetragonal system al o known by the name vesuvianite Cry tal frequently well formed are usually prismatic with pyramidal terminations It commonly occurs in columnar ag gregates but may be granular or massive The luster is vitreous to resinous the color is usually green or brown but may be yellow blue or red Hardness is $6\frac{1}{2}$ on Mohs scale specific gravity is 3 35–3 45 *See* SILICATE MINERALS





P mat c crystals of m neral docrase showing pyram idal te m atio s *(From C S H rlbut Jr Da a s Ma ual of M e alogy 16th ed W ley 1952)*

The composition of idocrase is expres ed by the formula $Ca_{10}Al$ (Mg Fe) Si O $_4(OH)_4$ Magne sium and ferrous iron are present in varying amounts and boron or fluorine is found in some varieties Beryllium has l een reported in mall amounts

Idocra e is found characteristically in crystal line limestones resulting from contact metamor phism It is there associated with other contact minerals such as garnet diop ide wollastonite and tourmaline Noted localities are Zermatt Switzerland Christiansand Norway River Vilui Siberia and Chiapas Mexico In the United States it is found at Sanford Maine Franklin New Jer ey Amity New York and at many contact metamorphic depo its in western state A compact green variety resembling jade is found in California and is called californite [C S HU]

Igneous rocks

Tho e rocks which have congealed from a molten mas They may l e composed of cry tals gla or both depending on the conditions of formation The molten matter from which they come i called magma where erupted to the surface it is com monly known as lava Solidification of the h t r ck melt occurs in re pon e to lo s of heat Generated at depth the magma tends to ri e It commonly l reaks through the earth s crust and spill out on the earth s urface or ocean fl or to f rm volcanic or extrusi e rocks At the surface where cooling i rapid fine grained or gla sy rocks are forme l

Where unal le to reach the surface magma cool more sl wly in ulated l y the o erlying rocks and a coar er texture de el ps The re ulting igneou rock appear intrusive relati e to adjacent rock In general deeply f rmed (plutonic) rocks di play the coar est texture Igneous rocks formed at hal low depths (hypaby sal) display features ome what intermediate between those of volcanic and plutonic types *See* MAGMA PLUTON VOLCANO VOLCANOLOGY

Textures of igneous rocks Texture refers to the mutual relation of the rock constituents within a uniform aggregate It is dependent upon the rela tive amounts of crystalline and amorphous (gla y) matter as well as the size hape and arrangement of the constituents

Rock textures are highly significant they hed light on the problem of rock gene is and tell much about the conditions and environment under which the rock formed

Crystallinity This property expresses the pro portion of crystalline to amorphous material in an igneous rock Most igneous rocks uch as granite are compo ed entirely of cry talline material and are called holocrystalline Entirely glassy or holo hyaline rocks such as obsidian are extremely rare Many rocks such as rhyolite or vitrophyre contain both glass and crystals and are called hypocry tal line or hypohyaline

Glass may be considered an amorphou oli l with no systematic arrangement of its con tituent atoms Crystals form as the temperature of a magma falls and atoms begin to arrange them el e into orderly repetitive group With rapid cooling there may l e no opportunity for cry tal to de el p and a magma will congeal a glas

Granularity or grain size In igneous rock grain size ranges widely and depend in large part upon rate of cooling Rocks are phaneric or phanero cry talline if their constituent mineral grain can be distinguished as individual entitie l y the naked eye All other igneous rocks are aphanitic

Phaneritic rocks are divided according to a er age grain diameter as follows fine grained grains le s than 1 mm medium grained grain 1 5 mm coar e grained grain 5–30 mm very coar e grained (pegmatitic) grains more than 3 cm

Aphanitic rocks are microcry talline if indi i l ual c nstituents can l e di tingui he l only with th micro cope They are cryptocry talline if n tit uent are sul micr copically ry talline D mi nantly gla y rock are con ider d aphanitic A f anitic rock rich in light col red (fel i) mineral are termed fel itic *See* FELSITE

Grain shape In igne us rock grain hap i n tr lled l y many fact r In l ighly gla y r k th rate of gr wth i imp rtant Cry tallit (Fig 1) are the mo t rudimentary f rm an l al un l in gla sy rock in which raj i l n li lati n l r re ted f rtl er growtl They are t o mall t j lar ize light and cannot l id ntif e l a t m r l specie The e emf ryonic f rm ar j rtay n t aried an l l eautif illy di j l ye l in th gl k pitch t ne *See* OBSIDIAN

Micr lite are slightly larg r el ngat ry t l They p lariz ligl t and can u ally l i l ntif l specifi ally un l r tl micr ope Many l a

gr n rap dly b t imp rf ctly to form keletal cry tal (Fig I)

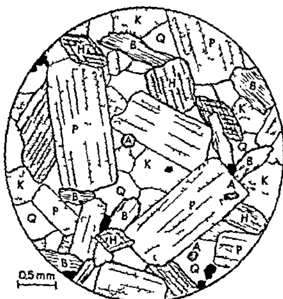
I most rocks, g ain hape cont lled larg ly by quen e of m neral crystallizat on nd the a t r and a ty f a soc ted mi ral A grain i sa d t be e hed al f bounded by it cl aract r t c ryst l faces and nhedral if cry tal f es are ab- se t. Intermedi te forms ar subhedral Crystals dev loped early in a magma t nd to be euh dral Lat ry t l h we er meet nt rfer nce f om n m ous adjac nt gra s and are forced to a sum irr gula mutu l bo ndaries

It i not neces ry that all m tually inte feri g gr n de elop a hed l form Some mi eral pe- c s po e s a greater p wer of g owth (great r fo m ene gy) and are apabl f m int in ng the r har cte i ti cry tal form competiti n w th ad j ce t m e al

Mo t igneous ocks how a g ny o g anular t tu in h ch the m jor ty f ry t ls are roughly equid me ional Ra ely g a ns with e he d al o th e d m nate nd gr th rock an idio- m rph granul r textu e M r mmonly nearly all gra n are anhed al and the ock texture i all tri m rphi g anul r Mo t r cks how an in t rmediate or hyp d omorph c g nular te tur (Fig 2)

Po phy it c textu e Th gr n s e f om igne- rocks s extr mely un form (equ gr nular tex t e) but that of the may be h ghly inequ gran ul r R ck in wh ch r lati ly large rystals (phe- nocry t) ar d p r ed in m tr x ground n ss f fi r g a ed r gl ssy materi l ar id t b po phy ti ph c (F g 3) P rphy t c glas es th b dant ph ryst ar kn spec fi ally a tr phyres

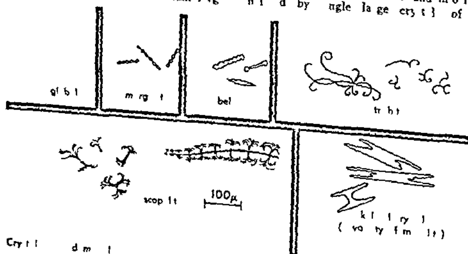
P rph it r k m y f rr i a umber of ways (1) Ph oc y ts m y h gr wn arly a d lowly h le th magma wa de pl b ied The g u d ma m y ha e g aled lat r aft r th m gm w rupted t h ghe lev l whe apid cool n en ed ( ) Phenocry t n many ock (som gran t) m y d el p lat and st ll attain l rg



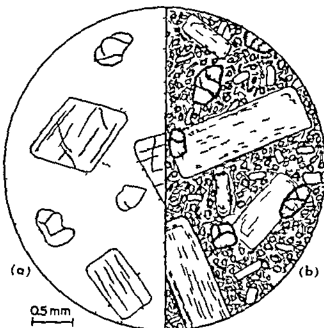
Fg 2 *Hyp d morph c g a ul t t g o od o- t Euh d al pl g cl s (P) bhed al ho nbl de (H b t t (B) hed l q rtz (Q) d pota h feld pa (K) Ac e ory m e ls l d h d al p t t (A) d ubhed l mag et t (bla k)*

dimen ons if the r growth rate i sufficiently gr at r than that of adj c nt m ne al (3) The large ry t ls of s me pluton c rock are probably more prope ly la ed as po phy obla ts They may ha e formed s nt ally in ol d rock by re ry t l lizat on a ded by r id al fl id from the lid fyin magma. (4) Large ry tal in m ny rocks (rta n p rphy ies nd l mp ophyres) may not b indigen s They may ha e be n inco po ted du ing trusion f th m gma (5) Ph no ry ts might de el p by no ul ti or by d t b nce of s per sat ated magma S LAMPROPHYRE PHENO CRYST PORPHYRY

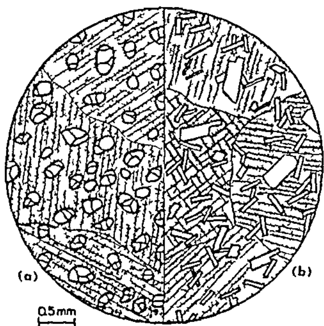
Po k l tic text Thi text e invol e numerous mall g ains of one m neral in and m o i ntat n l d by ngle la ge ery t l of another



Fg 1 Cry t l d m l



Fg 3 Porphy it c te tu es (a) Porphyr t c rhyol t how g euh d al phenocrysts of san d e and e so bed crystals of qua tz in a bmic o copically crys tall e matr x (b) Po phyrit c basalt showing euhedral phe ocrysts of plag oclase a d subhed al ol ne a mat x of g anular py o e e and feldspa m c ol tes



Fg 4 (a) Po k l t c te t re w th l rg crystal of h nbl de enclo g ab d t small g ains of ol v e (b) Oph t c t tu e w th l rge cryst ls of py o e en cl g small l th of plagiocla

(Fig 1r) Conditi n fa ring de el pm nt f p i kilitic t xture are n t well under tood In ome rock th i texture may have de el ped l y direct cry tallizati n f magma In cth r r ck thi tex tur may repre nt recry tallizati n of magmatic rock

Ophitic texture Thi i a pecial type of poikili ti t xture an l i hara teri tic of th rock dial a e (Fig 1f) Th texture inv lve lath l aped crystal of plagiocla e feld par enclo ed l y large anhedral grain or plates of pyroxene (augite or pigeonite) If the length of the feld par cry tal exceed that of the pyroxene enclo ure i only partial and the tex ture i called ubophitic *See* DIABASE

Other texture more or le related to ophitic *are characteri tic of very fine-grained and gla y* rock of basaltic compo ition *See* BASALT

Implication or intergrown textures The e are formed by the mutual penetration of two or more mineral pha e The intergrowth may l e so inti mate that one pha e appear di integrated into smaller grains which are i olated by the other Within mall domains however grain of one pha e show optical and cry tallographic c ntinuity

Graphic or micrographic textures may develop between almo t any mineral pair where one mem ber in cuneif rm ma e re eml ling runic in rip tion is enclo ed by the other (Fig 5a) Micro pegmatitic texture is e entially a micrographic texture involving only quartz and p ta h feld par (Fig 5b) If the intergrowth i more varied and invol es plumo e fringing radial or micr peg matitic pattern the texture i granophyric (Fig 5c) In myrmekitic texture plagi cla e (gen erally oligocla e) grains enclo e vermicular quartz (Fig 5d) Perthitic texture i extremely common in feld par and take on a wide variety of form (Fig 6) It u ually con i t of tiny ma e f s lic plagiocla e enclo ed l y pota h feld par Vari u pr p rtion of the two con tituent may exi t Where pota h feld par i more al undant an l c n titute the ho t mineral the material i kn wn a perthite Where plagi la e pred minate the material is called antiperthite

Some implication textures may develop l y simul tane us cry tallization of two c n tituent Other may f rm l y ex oluti n in the olid tate (s me perthite) Still other texture may be d ie to the partial replacement of one mineral pha e l y an other

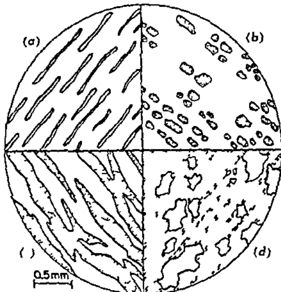
Structures of igneous rocks Structure as ap plied to igne u rock i a ily confu ed with tex ture In gen ral howev r tructure r fer t a g metrical f rm or ar hitectural feature in a rock Stru ture emp ha ize the heterogene u nature of *a ro k or mineral aggregate texture emp ha iz* homogeneity C rtain larg ale tru tur u h a fault f ld and j int are mm n t mo t rock type They are perhap m r pr p rly cla e l a geol gic tructur l ike textur the truct ire of igneou r ck may tell m i h al it t l i t ry r nditi ns of f rmati n f th r k them elve

I ular structures The structur ar i m n in many lcanic r ck They f rm wl n m gma i l rought to or n ar the earth rfa II re the l w pre ure p rmit partial r l a an l xp n i n f li l l water r th r v latil an l th f rmati n of team l ul l l which may l pre erved a mall cavities wl n th m gma ng l In h gl ly vi cou la a (rl y lit) m i h ga may l trapped l it nly tiny l ul l l may f rm Rapi l

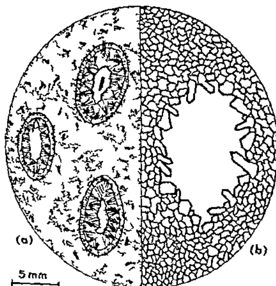
ool g f th f thy l quid p od s a pum ceo s tru t re (h a ter tic f th r k pum c) In le c la a (ba alti) nt rati of ti y bubl l p od es a c ar er p ngv o co i ceo tr cture (cha acte i ti f th ock or a) Ve- l ton f s m ba lt c la s pr du e well f rmed ell pso dal c iti Th e may later l fill d th m eral (u h a qua tz, cal ite ep d t eol t) dep ted fr m fl id wh ch p m ted th rock Such fill ng re called amygdul s i llu to th i lm d h pe Th tru t e is k wn a mygdal d l (F g 7a)

M a ol t ope ing Th ar the m st omm n ca n u tructu fou d n pluton c rock They a e rr gular ra ge up to several in he a nd app ar cru t d w th beaut fully fo m d c y tal (q rtz a d feld par) The c y t l are n t truly r t g a a ty w ll th b es co t t t a teg al part f the o k (Fig 7b) Th s fa t d tes that a h a tv (vug) f med a a m ll t t r p c n the cry tal aggr gate a d filled with res d l magr atic fl d aga n t wh ch bou d g g d ly de l ped tl i uhed l th e Th pres c f m te tourm l ne top z, and ap t te g t th t l t l (wate flu i and bor n) wh h o t t n e idu l m gm t fl id l pl yed a mp rta t ole in th devel p m t f m lt t u tu Th a it ar mo t l k ly t f m in ks c y tall z ng t hall w d pth whe f g pres s lati ly low

Z d y t ls C y tals p s ng zon l st t es r comm n a d pp a to be b lt up f co tri hell r es f d ffe ent mp s t n sh h f ll w the g af ry t l outl n (F g 8) Th gh m nute thes z n l tr t es a eadily d t i d th n ct n und th m c o c p I d d al e may b th k or th nd z ed



Fg 6 P rth t t t ( ) St g p rth t (b) P t h p rth t ( ) V perth t (d) A t p rthit



Fg 7 ( ) Amygd lo d l t t h w g f m ga t (b bbl) l fill d w th l f m ols (b) M (t ty f e-g d g o t w th all t o- m ph g lo t t E h d of tl bl ly wh ryst l f m ty b d y

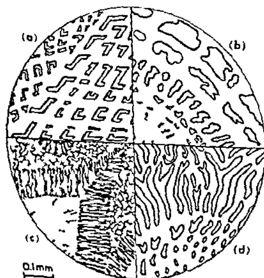
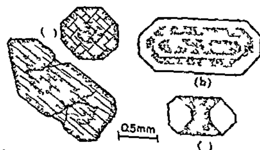


Fig 5 Impl t g w t t ( ) M o- g phic t t (b) M opegm ti te t ( ) G o- phy ic tu (d) Myrm k t t t



Fg 8 ( ) Z d ry t l f py plag cl ( ) H gl t ct (b) Z ed py

boundaries may be sharp or gradational. Compositional changes from the crystal's center outward may be great or slight; they may be progressive, reversed, interrupted, oscillatory, or repetitive. Zoning is characteristic of minerals belonging to solid solution series (for example, plagioclase, pyroxene, and amphibole).

Numerous theories have been proposed to explain various types of zoning in minerals. These are based on physical chemical principles relating to supersaturation of the magma and changes in composition, pressure, temperature, and volatile content of the magma. Movement of crystals from one part of the magma chamber to another may have been important. The most common type of zoning (progressive) appears because of incomplete reaction between solid and liquid phases during the crystallization of an isomorphous series.

Hourglass structure. This structure, somewhat related to zoning, is most frequently displayed by crystals of pyroxene. Certain sections through a crystal possessing the structure have the appearance of an hourglass (Fig. 8). This structure probably demonstrates the minute differences in energy involved at different faces of a growing crystal. It may be due to selective adsorption of ions by different faces during crystal growth.

Reaction rims. These rims or zones in which one mineral envelopes another are believed to have formed by reaction and are common in some rocks (Fig. 9). They may develop by reaction between early formed crystals and surrounding magma

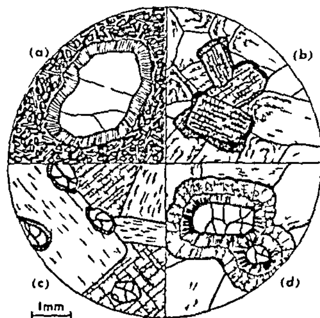


Fig. 9. (a) Reaction rim of pyroxene around quartz grain in basalt. (b) Reaction rim of hornblende around three grains of orthopyroxene; rest of rock is composed of plagioclase. (c) Reaction rim of orthopyroxene formed between small olivine grains and plagioclase; the rest is composed of plagioclase. (d) Reaction rims of olivine, formed of orthopyroxene, with outer rim of amphibole.

(pyroxene rims on early formed olivine crystals). Reaction between two incompatible minerals induced by residual fluids in the late stage of magma consolidation may produce similar effects. Pyroxene or amphibole may form by reaction around olivine crystals where they would otherwise come in contact with plagioclase. Some petrologists refer to rims of primary origin as coronas and those of secondary origin as kelyphitic borders.

Spherulites. These are radial aggregates of needlelike crystals. They are roughly spherical and usually less than a centimeter across (Fig. 10). They abound in silica-rich lavas, particularly rhyolitic glass, and are composed principally of quartz, tridymite, and alkali feldspar.

Somewhat similar aggregates in basaltic rock called varioles consist of radial plagioclase crystals with interstitial glass or granules of olivine or pyroxene.

Spherulites consisting of concentric shells with cavernous interspaces are known as lithophysae or stone bubbles. In many, the tiny annular cavities are lined with delicate crystals of cristobalite, quartz, and feldspar.

Inclusions or enclosures. Inclusions are common in most varieties of igneous rock. These masses of extraneous looking material vary widely in size, shape, constitution, and origin. Inclusions demonstrated to be foreign rock fragments enclosed and trapped by congealing magma or lava may be specifically designated as xenoliths. Incorporated foreign crystals are known as xenocrysts. *See* XENOLITH.

If an earlier consolidated portion of a magma is ruptured and fragments of it become enclosed by portions which solidify later, the older rock bodies are known as autoliths. Enclosures formed by selective accretion of minerals either during or after consolidation of a magma are termed segregations.

Orbicular structures. These structures, found in some plutonic rocks (granite, granodiorite, and diorite), are orblike masses generally up to a few inches across. They show concentric shells of different mineral composition and thickness which may envelope xenolithic cores (Fig. 11). Most commonly, dark mineral shells (rich in biotite, hornblende, or pyroxene) alternate with light shells (rich in feldspar). Individual shells may be sharply or vaguely defined, and the minerals within may be granular or elongate and in radial or tangential arrangement.

Orbicular structures may develop by reaction between xenolith and magma involving chemical reconstitution of the solid fragment or rhythmic crystallization around xenolith. Many orbicular structures may represent products of metamorphism and metasomatism of solid rock. See METAMORPHIC ROCKS; METAMORPHISM; METASOMATISM.

Ellipsoidal structure. This type of structure is a peculiar feature of certain lava flows (basalt, spilite). Rocks exhibiting this structure appear to be composed of closely packed pillow

haped m es up t eral feet r s Indn dual p ll ha e a e fine-grai ed rust or margin wh ch arrie bundant i l commo ly ar r nged e nc ntr lly with the p llow surfac

The p ll w re o p f ctly fitted t gether as t sugg t th t they we e as embled in a pl t c tat R lat el l ttl matr x cc r and it n ts c m m nl f chert, l me tone o hale The cl e a soc t o f p llow l a w th ed m nt ry r ck i in agreeme t with the pop l r belief th t th y ar of ubaqueou o igin Pill w lav s ha e b en observed t f rm both n dry land a d n wat r b t the p c o dit n fa r g the r f mati n ar till not ll nd r t od *Se* SPILITE *s e l o* PRECAMBRIAN

Fl w st u tu Th i a nongenet term f r a mber f dir ct fe t e in ro k Th t u tu e m y be f rmed by fl wage d r ng cry tall zat on f a magma (pr m y fl w st ture) I o t olidifica t n fl w (eco dary) m y de el p similar fea t but the e a e cl s ed as metam rphi in i gi

Th tr tur tak the f rm f par ll l st e ks r len es of d ffere t min r l o t xtu es o it may r ult f om parall l a geme t of elo gate pl t min r l (mi h nble d o f ld p r) Sm fl w tru t re o t of ab nda t labby lu i n n l ths in p allel r entat on Fl ge may b xpre ed by fl w l e (l ne t on) r fl las (me foli t o) Th e may b l ght t rt d

Fl d l t t e and flux st tu e The e g n t term a d p e fic lly imply fl wag f la a m gr a (F g 10c)

S hl S hl e g l tr aks p t h l s ha i g m l ble ded o t l nes nd m u g p t m y fe t n l gth

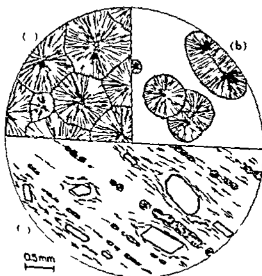
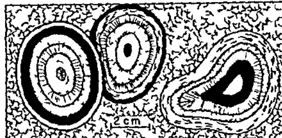


Fig 10 ( ) Sphe l c truct vol pl ( ) Fl d l tru tu (b) Sph rul i l ph l ph ocry ts, m f h w g t of d ry t ll i



Fg 11 Ob l t ct

They ar ge erally c mp sed of th ame m n ral s the e clo ng ock but in different proportions Schli ren may repre ent a l se regati n drawn ut by magma fl w Some m y be xe olith more or l d gest d and rew rked by magma Othe s may ep ese t re idual magmati l quors f d fferent c mp t n njected into alre dy crystalli ed por tion Schl e en formed n solid r ck are more pr perly met mo phic or meta omatic feature S GRA ITIZATION

Band ng Banding i exhib ted by rocks com p ed f altern ting layer f differ nt c mpo ition text re or ol r The term is m r ly de cripti e not g n t c If flow ge i t be impl ed the term fl w b nd n u ed

Classification of igneous rocks Sch mes for la ify ng igne u ock ar numer u *Prior to the ad e t f th* pol rizing micr pe (roughly 18 0) r k las ficat on re ba ed on mega pi ch ra te st cs many f them m slead ng The yst m w re g du lly imp ed a ch m l analy were more commo ly employed

Today th pr nc pal methods of classificat on a u d (1) M ga c p c ch mes are bas d o th appeara e f th r k in hand pec m n as en w th m gn fyi g gl s (hand len) S ch s hemes ar ful i th fi ld t dy of *ro* ks (2) Mic o- c pic *cheme* (la g ly m n alog al) are em pl y d in lab ato y *in* e t at n wh re more de- t led nf m t on is need d (3) Ch m cal sch mes a e e u ful but ha e mo e l mited appl cati n The m ne al c ntent and t tu e f a r ck g nerally t ll m ch mo abo t the o ks r gin tha d a b lk h mic l naly F xampl gran te q rtz p phyry rhy l te and ob d n m y all h v th ame he al comp tion l t the ge log c con d t s u d wh ch ch f m may be ry diffe ent Gran t sol d fies l wly at d pth a d u der h gh p e u e The po pl yry may rystall n tw stages ne at d pth a d a l t nearer the s r fa e The oth tw o ks a e f u fic al o g n th l d olid fi s most p dly nd a glass

Igneou ck l w gr t a t n hem ally min l g ally textu ally nd t u t ally w th few if any nat al b und es Th c unts i l g pa t f th g at di agr m nt m ng petrol gi t t h w igneou r ks h uld b cla sified The f llow ng sub ect s d plutonic l c d hyp by l typ

Pl t c r cks Pluton c rock o c n larg n tru m es (bath l ths stock a d other l ge

plutons). They form at great depth and therefore are often referred to as abyssal rocks. Generated from large bodies of magma which has cooled slowly, they characteristically show a phaneritic holocrystalline texture.

Under deep-seated conditions where confining pressure is high, volatiles dissolved in the magma are retained until the last stage of crystallization. These act as fluxes and reduce the temperature of crystallization. Consequently plutonic rocks as compared with volcanic rocks may carry relatively low-temperature mineral phases.

Volcanic rocks. These are formed as lava flows or as pyroclastic rocks (heterogeneous accumulations of volcanic ash and coarser fragmental matter). They have solidified rapidly to develop an aphanitic texture with more or less glass. Volatiles are readily lost as the lava reaches the earth's surface. Therefore crystallization tends to proceed within a relatively high temperature range. Consequently high-temperature minerals such as sanidine and high-temperature plagioclase are characteristic. Expanding gas bubbles formed by escaping volatile frequently create highly porous rocks.

Volcanic rocks frequently show evidence of two stages of cooling, an early deep-seated stage (intratelluric) and a later effusive stage. Slow cooling in the first stage may produce a few large crystals. These become suspended in the lava and frozen into an aphanitic matrix during the effusive stage. This accounts for the porphyritic texture so commonly encountered in volcanic rocks.

Hypabyssal rocks. These rocks exhibit characteristics more or less intermediate between those of volcanic and plutonic types. They differ from volcanic rocks in that they are intrusive and generally free from glass and vesicular structures. They differ from plutonic rocks in that they occur in small bodies (dikes and sills) or in larger bodies formed at shallow depths (laccoliths) and they have textures characteristically resulting from more rapid cooling. Hypabyssal rocks cannot be sharply distinguished from volcanic rocks on the one hand and plutonic rocks on the other. The recognition of such a group therefore is perhaps of greater value in field studies where mode of occurrence is known than in the laboratory.

The rocks of each subdivision (plutonic, volcanic, and hypabyssal) may be further divided into families (*groups with the same or closely allied composition and relatively limited textural variation*). Families are sometimes grouped into rock clans. A clan includes all families with the same chemical composition. Thus the gabbro family (plutonic), diabase family (hypabyssal), and basalt family (volcanic) have the same chemical composition and therefore belong to the same clan (gabbro clan). The clan name is derived from the plutonic family member.

The principal families of the phaneritic (plutonic) and aphanitic (volcanic) rocks are shown in Table 1. This scheme expresses something of the *bulk chemical composition of the rock and the conditions of formation.* More specific rock types may be indicated by prefixing some pertinent mineral, textural, or structural term to the appropriate family name (such as biotite granite, graphic granite, orbicular granite). See PEGMATITE.

Chemical composition of igneous rocks. By averaging a large number of chemical rock analyses, one may derive a representative composition for each of the rock families. Average analyses for the more common igneous rocks are shown in Table 2. Such average values are very useful standards for

Table 1. Classification of igneous rock families

	Feldspar	Quartz	Quartz or feldspathoid ( )	Nepheline	Leucite
Alkali feldspar and plagioclase (oligoclase or andesine)	Alkali feldspar 50 of the feldspar	Granite (P) Rhyolite (A)	Syenite (I) Trachyte (A)	Nepheline syenite (I) Phonolite (A)	Leucite phonolite (A)†
	Alkali feldspar [illegible]0 of the feldspar	Granodiorite (I) Quartz latite (A)	Monzonite (I) Latite (A)		
	Alkali feldspar [illegible] of the feldspar	Quartz diorite (I) (tonalite) Dacite (A)	Diorite (I) Andesite (A)		
			Anorthosite (I)		
Labradorite-anorthite			Gabbro (I) Basalt (A)	Theralite (I) Tephrite (A)	Leucite tephrite (A)†
			Diabase (H)	Basanite (A)	Leucite basanite (A)†
Plagioclase < 10%			Peridotite (I) Pyroxenite (I) Hornblendite (I)	Nephelinite (A) Nepheline basalt (A)	Leucitite (A)† Leucite basalt (A)†

* See article by this title. † See LEUCITE ROCK.
(I) Phaneritic (plutonic) rock. (A) Aphanitic (volcanic) rock. (H) Hypabyssal rock.

mp ri n pit of th fa t that the ar at ons w th n f m l es m y be gre ter th n those b twe n fam l es.

Mineral composition of igneous rocks Igneous ock f rm ng m al may be cla ed a pr mary se o d ry The pr m ry mn rals ar th e formed by direct cry tall zation f m the magn a Se ondary minerals may form at a y sub quent t me

Ess tt l p imary minerals The principal pri mary mi erals a e rel tively few and may be l ss d as light col red (fel i) or d rk col red

T bl 2 Average chemical compositions of gneous rock (fter D ly) (t tals educed to 100%)

Compo ts	Pl to rocks							
	G an t	Grar o-d o te	Quartz d it	Sy te	M n o-n t	D o t	Gabbro	Nepheline syen te
S O	0 18	6 01	61 59	60 19	56 1	6 7	49 4	54 63
T O	39	57	66	67	1 10	84	9	86
Al O	14 47	15 94	16 1	16 8	16 96	16 67	17 88	19 89
Fe O	1 57	1 74	54	74	93	3 16	3 16	3 3
FeO	1 78	6	3 77	3 8	4 01	4 40	5 9	0
M O	1	07	10	14	16	13	13	3
MgO	88	1 91	80	49	3 7	4 17	7 51	87
CaO	1 99	4 4	38	4.30	6 0	6 4	10 99	2 51
N O	3 48	3 0	3 37	3 98	3 67	3 39	55	8 6
K_2O	4 11	7	10	4 49	3 76	1	89	46
H O	84	1 04	1	1 16	1 0	1 36	1 4	1 3
P_2O	19	0	6	8	47		8	

Compon ts	Aph t ocks							
	Rhy l te	Q tz lat te	Da te	Tra hyte	Latite	Andes t	B salt	Pho olit
S O	80	6 43	65 68	60 68	57 6	59 59	49 06	57 4
T O	33	8	57	38	1 00	77	1 36	41
Al O	13 49	16 1	16	17 4	16 68	17 31	15 0	0 60
Fe O	1 4.	4 04	38	64	..9	3 33	5 38	3
F O	88	1 0	1 90	6	4 0	3 13	6 37	1 03
M O	08	09	06	06	10	18	31	13
MgO	38	1 4	1 41	1 1	3.2..		6 17	30
C O	1 0	4 4	3 46	3 09	4	5 80	8 9	1 0
N O	3 38	3 34	3 97	4 43	3 59	3 58	3 11	8 84
K_2O	4 46	3	67	5 74	4 39	04	1 5	5 23
H O	1 47	1 90	1 0	1 6	91	1 6	1 6	04
P O	08	7	15	4	36	6	4	1

T bl 3 App oxim t mi ral composition of th common plut n c ock

Rock	F ls m rals %	%	M fi min als	%
Gra t	P tass m f ld pa 35–4 Sod pl giocl se 0–30 Q rt 0 30	80–9	B otite h nbl nd	5 0
Gra od te	P tass m f ld par 15 –5 Sod pl gioclase 35–4 Q rt 1 –5	5–90	B t te hornbl nd	10–
Q rt d rite	Oligocl se ndes 55–6 Q tz 1 –5	0–8	H rnbl d b ot t pyro e	15 30
Syen t	P t m f ld pa 0 5 P t m f ld pa 60 0 Sod pl gioel se 10– 0 Qu t ¡l l 0–5	0–90	B ot te h rnbl d pyro e	10 30
M on te	P t ss m f ld pa 0–30 Sod pl giocl se 4 5 Q tz or ph l 0–5	65 85	B t t hornbl nd pyro n	15 3
D rit	Ol gocl se des 60 0 P t ss m f ld pa 0– Q t ph l 0–5	60–80	H rnble d b ot t pyrox n	0–40
G bbro	Labrad rit b yt w t 0 45– P t m f ld pa 0 Q tz pl l ne 0		Pyro ne l h rnbl d b ot t	5

plutons). They form at great depth and therefore are often referred to as abyssal rocks. Generated from large bodies of magma which has cooled slowly, they characteristically show a phaneritic holocrystalline texture.

Under deep-seated conditions where confining pressure is high, volatiles dissolved in the magma are retained until the last stage of crystallization. These act as fluxes and reduce the temperature of crystallization. Consequently plutonic rocks as compared with volcanic rocks may carry relatively low-temperature mineral phases.

Volcanic rocks. These are formed as lava flows or as pyroclastic rocks (heterogeneous accumulations of volcanic ash and coarser fragmental matter). They have solidified rapidly to develop an aphanitic texture with more or less glass. Volatiles are readily lost as the lava reaches the earth's surface. Therefore crystallization tends to proceed within a relatively high temperature range. Consequently high-temperature minerals such as sanidine and high-temperature plagioclase are characteristic. Expanding gas bubbles formed by escaping volatiles frequently create highly porous rocks.

Volcanic rocks frequently show evidence of two stages of cooling: an early deep-seated stage (intratelluric) and a later effusive stage. Slow cooling in the first stage may produce a few large crystals. These become suspended in the lava and frozen into an aphanitic matrix during the effusive stage. This accounts for the porphyritic texture so commonly encountered in volcanic rocks.

Hypabyssal rocks. These rocks exhibit characteristics more or less intermediate between those of volcanic and plutonic types. They differ from volcanic rocks in that they are intrusive and generally free from glass and vesicular structures. They differ from plutonic rocks in that they occur in small bodies (dikes and sills) or in larger bodies formed at shallow depths (laccoliths) and they have textures characteristically resulting from more rapid cooling. Hypabyssal rocks cannot be sharply distinguished from volcanic rocks on the one hand and plutonic rocks on the other. The recognition of such a group therefore is perhaps of greater value in field studies where mode of occurrence is known, than in the laboratory.

The rocks of each subdivision (plutonic, volcanic, and hypabyssal) may be further divided into families (groups with the same or closely allied composition and relatively limited textural variation). Families are sometimes grouped into rock clans. A clan includes all families with the same chemical composition. Thus the gabbro family (plutonic), diabase family (hypabyssal), and basalt family (volcanic) have the same chemical composition and therefore belong to the same clan (gabbro clan). The clan name is derived from the plutonic family member.

The principal families of the phaneritic (plutonic) and aphanitic (volcanic) rocks are shown in Table 1. This scheme expresses something of the bulk chemical composition of the rock and the conditions of formation. More specific rock types may be indicated by prefixing some pertinent mineral, textural, or structural term to the appropriate family name (such as biotite granite, graphic granite, orbicular granite). See PEGMATITE.

Chemical composition of igneous rocks. By averaging a large number of chemical rock analyses one may derive a representative composition for each of the rock families. Average analyses for the more common igneous rocks are shown in Table 2. Such average values are very useful standards for

Table 1. Classification of igneous rock families

	Feldspar	Quartz	Quartz or feldspathoid (?)	Nepheline	Leucite
Alkali feldspar and plagioclase (oligoclase and andesine)	Alkali feldspar > 2/3 of total feldspar	Granite (P) Rhyolite (A)	Syenite (P) Trachyte (A)	Nepheline syenite (P) Phonolite (A)	Leucite phonolite (A)†
	Alkali feldspar 1/3–2/3 of total feldspar	Granodiorite (P) Quartz latite (A)	Monzonite (P) Latite (A)		
	Alkali feldspar < 1/3 of total feldspar	Quartz diorite (P) (tonalite) Dacite (A)	Diorite (P) Andesite (A)		
			Anorthosite (P)		
Labradorite-anorthite			Gabbro (P) Basalt (A)	Theralite (P) Tephrite (A)	Leucite tephrite (A)†
			Diabase (H)	Basanite (A)	Leucite basanite (A)†
Plagioclase < 10%			Peridotite (P) Pyroxenite (P) Hornblendite (P)	Nephelinite (A) Nepheline basalt (A)	Leucitite (A)† Leucite basalt (A)†

*See article by this title. †See LEUCITE ROCK.
(P) Phaneritic (plutonic) rock. (A) Aphanitic (volcanic) rock. (H) Hypabyssal rock.

c mp son in pite of the fact th t the ariatio s w th f m l es m y be great r than th b tween f m l es

Mineral composition of igneous rocks Igneous ock f rming mi rals may be l ed a pr m ry ec ndary Th p imary m neral are thos f rmed by di ect cry tallizat on f om the magma Se ndary m neral may form at any b equent t me

Esse ti l p imary m erals The principal pri mary mi erals are relati ely few and may be las ed as light colored (felsic) or dark colored

Tabl 2. Averag hemical composit ons of igneou rocks (fte D ly) (totals ed ced to 100%)

Compon nts	Plut nic rocks							
	Cra it	Grar o-d te	Qu rtz d o t	Sy nite	Monzo-te	D o t	Gabbro	N pl line syen t
SiO_2	0 18	6 01	61 59	60 19	56 1	56 77	48 4	54 63
TiO_2	39	57	66	67	1 10	84	97	86
Al_2O_3	14 4	1 94	16 1	16 8	16 96	16 6	17 88	19 89
Fe_2O_3	1.57	1 74	1	4	93	3 16	3 16	3 3
FeO	1 78	6	3 77	3 8	4 01	4 40	5 9	0
MnO	1	07	10	14	16	13	13	3
MgO	88	1 91	80	49	3 7	4 17	7 51	87
CaO	1 99	4 4	5 38	4 30	6 50	6 4	10 99	.ol
Na_2O	3 48	3 70	3 37	3 98	3 67	3 39	.55	8 6
K_2O	4 11	75	10	4 49	3 6	I	89	5 46
H_2O	84	1 04	1	1 16	1 0	1 36	1 4	1 3
P_2O_5	19	0	6	28	47		8	5
Compo ts	Aphan t rocks							
	Rhy l te	Q a tz l t t	D c te	Tr hyt	Lat te	Andes te	Basalt	Phon l te
SiO_2	7 80	(43	65 68	60 68	57 65	59 59	49 06	57 45
TiO_2	33	8	7	38	1 00	7	1 36	41
Al_2O_3	13 49	16 15	16	17 4	16 68	17 31	15 0	0 60
Fe_2O_3	1 4	4 04	38	64	.29	3 33	5 38	3
FeO	88	1 0	1 90	6	4 0	3 13	6 37	1 03
MnO	08	09	06	06	10	18	31	13
MgO	38	1 74	1 41	1 1	3.	7	6 17	30
CaO	1 0	4 4	3 46	3 09	5 4	80	8 9	1 50
Na_2O	3 38	3 34	3 97	4 43	3 59	3 8	3 11	8 84
K_2O	4 46	3 7	67	5 74	4 39	04	1	5 3
H_2O	1 47	1 90	1 50	1 6	91	1 6	1 6	04
P_2O_5	08	7	15	4	36	6	4	1

T bl 3 Appro im te m eral composit on of the mmon pluton ocks

Rock	F l minerals %	%	M f c minerals	%
Gra t	P tass m f ld pa 35–45 Sod pl g oclase 0–30 Q a t 0–30	80–9	B t t h nbl nd	5- 0
Gra odiorit	P ta m f ld pa 15 – Sod pl g ocl se 35–4 Q t 1 –	10	B t t h rnblend	10–
Qua t d rit	Oligocl se des 55–6 Q t 15 –	0–85	H rnbl d b t t py o e	15–30
Sy t	P ta m f ld pa 0–5 P ta m f ld pa 60– 0 Sod c pl gioclase 10 0 Qua t ph l n 0–5	0–90	B t te h rnbl d pyro ene	10–30
Mon t	P t s m feld pa 0–30 Sod pl gioel se 45–5 Q t nepl l 0–5	65–85	B t t h rnbl d pyro	15 3
D t	Ol gocl se a des 60– 0 P t m f ld pa 0– Q t ph l 0–	60–80	Hornbl d bi t t pyro n	0–40
G bbro	Labrad t t yt t 5 0 4 P t um f ld pa 0 5 Q t o neph l ne 0		Pyro l h rnbl d b ot t	2 5

(mafic) varieties Fel ic is a mnemonic term for feldspathic minerals (feldspar and feldspathoids) and silica (quartz, tridymite and cristobalite) Mafic is mnemonic for magnesium and iron rich minerals (biotite amphibole pyroxene and oli vine) Fel ic minerals are compo ed largely of silica alumina and alkalie Mafics are rich in iron magnesium and calcium

Table 3 summarizes the essential primary con stituents of the more common plutonic rocks The percentage ranges are highly generalized Individ ual rock specimens may depart radically from these values but the averages are fairly representative and useful for comparison The mineral composi tion of the corresponding volcanic rocks is roughly similar to the values in the table Major departures will be encountered particularly in the glassy rocks

Accessory minerals Accessory minerals are those occurring in very small or trace amounts They con sist principally of magnetite ilmenite pyrite hem atite apatite zircon rutile and sphene Most gen erally the e are widely distributed as tiny grains or crystals

Secondary minerals Included in this group are minerals formed by addition of material subse quent to solidification of the rock or by alteration of minerals already pre ent in the rock The addi tion of fluorine and boron which tend to concen trate in the residual magmatic liquids to already crystallized portions of the rock may form small crystals of fluorite topaz or tourmaline Alteration in which certain minerals become more or less re constituted is common and widespread It is gen erally believed to occur during the la t stages of solidification while hot re idual fluids (for exam ple water and carbon dioxide) permeate the crystal aggregate and convert water free silicate minerals into l ydrous forms This hydrothermal or deuteric effect may be so inten e that virtually all igneous characteristics of the rock are lo t The common alteration product deri ed from the essential pri mary minerals are listed below

Primary mineral	*Secondary mineral*
Quartz	Not altered
I otash feldspar	Kaolinite sericite
Plamocl se	Kaolinite sericite (para onite) epidote zoisite calcite
Nepheline	Cancrinite analcite natrolite
Leuc te	Nepl eline and p tash feldspar
Sodalit	Analcite ancrinite
Biotite	Chlorite spl ene ep lote rutile iron oxi le
Hornl lende	Act nolite l i tite cl l rite epi dote calcite
Orthopyr xene	Anti orite actinolite talc
Clinopyroxene	Hornl lende actinolite b otit chlorite epid te antigorite
Olivine	S rpentine m netite talc mag nesite

Density of igneous rocks Den ity is a ignif cant rock pr perty and is a functi n largely of min

Table 4 Approximate densit es of some common plutonic rocks

Rock	Av g	C r ge
C anit	6	60 73
G a od it	l	6
Sy t	6	6 8
Q tz l t	8	9
D o t	8	7 9
C l b o	99	8 3 1

eralogical composition and poro ity Chemical composition alone is not a relial le indication of density becau e different minerals (with different den ities) may form from a single bulk compo i tion

Table 4 gives the approximate average and com mon range of density for the more abundant plu tonic rocks Densities of volcanic equivalents are generally slightly lower due to higher poro ity and greater amount of gla s Highly porous volcanic rocks (pumice and scoria) may be so vesicular as to float on water The density of coml letely gla y rocks is approximately 6% less than that of the corresponding holocrystalline (entirely cry tal line) type [C A CA]

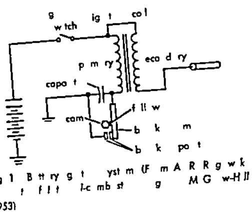
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Ignition system

The ignition system of an internal coml u tion en gine initiates the chemical reaction l etween fuel and air in the cylinder charge F r maximum effi ciency it is neces ary to ignite the charge in each cylinder shortly before the pist n reaches the top of its compression stroke The be t timing i de termined experimentally f r various engine sj eed and loadings and the igniti n system i de igned t provide this timing automatically For smo th running multicylinder engines are usually l uilt o that the various piston arri e at their firing t j center positi ns in e enly spaced interval Tl e e quence in which the cylinders reach tl eir firing points depends up n tl e ge metrical arrangement of the cylinders and crank haft and is called the firing order of the engine The igniti n y tem di tril ute the igniti n impul e to the cylinders in thi rder (*s e* DISTRIBUTOR)

A large clas of engine including m t auto mol ile engine operate n a premixed harge f fuel apor and air In the e engin the harge i ignited l y pa ing a l igh ltag l tri current l etween two electrode in the oml i ti n haml er (*see* SPARK PLUG) The ele tr le are in rj rated in a removal le unit When a spark f iff ient energy jump tl e gap l etwe n the ele tr d a elf pr p gating flame i pr duced in tl e fuel air mixture which j read raj i lly thr ugl o it th charg

Battery system Tl e el ctric energy f r the sj ark is oltai ed from a t rage l attery in pra tic lly all j ark igniti n engines Tl l tt y i n



g 1 B tt ry g t yst m (F m A R R g w k f f l t l-c mb st g M G w-H ll 953)

lly 6 r 12 lt ı part f a l w lta e p mary ı t whi h ncl d a switch the p ım ry w d g f the ıgnıtı n c l a p c tor (o c n d r) d b aker p nts (F g 1) Whe th w t h a d breake p t a e cl ed r t fl w f m the b tte y th gh the p ım ry w d g th ugh the p t a d b k t th b ttery th o gh the ng e f me r oth r gr u d c n ect n Th l w nd abo t oft ı on The urr nt ın th p m ry w nd ng ndu e magn t fi ld n d r d th c Whe th br ak p t p a th e g ed n am t tes the u e t, h h h d b e p ng th gh the po nt w fi ı t the apa t A th c p c to bec mes h rg d th p ımary nt f ll r p dly a d th m g t field c ll p

Th ec d ry w d g t f ma y t rn f fi e w re w d n the ame w th th p ımary d g The p d ll p of th m g et c field th c e ı du es ry hıgh lt ge ı the ec d ry w d g

W th t th ap ıt the p ım ry lt ge ed b th p d ll p e f the m g et fi ld d th p m y w d g w ld a e n rc the b e k p t Th rc w ld b rn th po ts d soo d t y them Th c pac to l t th p d d p th p mary cu nt and ll p f th m gn t fi ld b th f wh h eces ry f r th p d t n f the hıgh se d ry lt ge

Th ec d ltag led t th p k pl g p p q e by a tary w t h ll d th d t b t wh h d e by the m h ft th t d th b k po t m F m th he d f the d trıb t w ll ı lated w e ry th seco d ry lt ge t th t l lect od f the p k pl g Th d h rge wh h t kes pl betwee th t l lect od d the g ded elect de d th mb t h mb ıgn t th cyl nde h g

Th t m g f th gn t n p k t lled by th pe g f th b k r po t Th g tı t m g m be ed by otat ng th pl t po h h th b k po t m ted el t t th m T m g m lso be ed by h g g th g l l t h p betwee th b k am d th h ft that d es t.

Magneto system The magneto sy tem s s mılar to the batt ry sy tem e cept that the oltage re qu red to a e a fl w of current ın the prımary wı dı g ıs generated by th tat on of a et of p rmanent magnet ın t ad f beı g ı ppl ed by a battery The mag et as mbly n rmally ın l de w th n o e h u ı g the rotatıng magnets ıgn t on coıl wındı gs ı on core break r po nts am ap c t r and d t ıbut r (Fıg 2)

Rotatı n f the m gnet a mbly completely re e ses the d rect o f the ma netic flu ın th oft r n co e about wh ch the p ımary and econdary o l a e w und Thı r p d change ın fl x ıntensıty a d d ectı n d s a c rrent thro gh the pr mary cı t. Whe the pr m ry urrent eaches a h gh l e a d th c tr but on to the t tal fl x ıs prı ıpally f om th prım ry curre t a d n t fr m the p rm n nt magnets the bre k r p ınt open wıth the ame r s lt as ın the battery sy t m d scr bed

For ma ımum eco d ry voltag ıt s es e tı l that the b e ke po t open whe the p rma ent magnet ha e rea hed p rt cular pos tı n wıth respe t to the o l c re Any attempt to ary ıgnı to t m g by h ftı g the pe ng t me of the b eaker poınts w ll th r fo e r s lt ı a weake spark

Th magneto s ofte u ed n m ll ompa t ın t ll t on h a l wn m we d utb a d e g es n wh h a battery w uld r pre ent e tra bulk a d we ght a d req ıre replacement r re cha gı g t me In nstall tıon h autom bıl ın which a battery ıs equ red fo ı h other p r p ses a st t g pa k ng l ght d f el g ge o ın wh h o de ble a atı n gnıt n tım ı g ı ne es ry b ttery ıgn t n ystem s u u ally ch e

Compressıon ıgnıtıon In th d l or omp s s n g ıt n e gı e the nd t d cyl de r ıs he ted uffi e tly by th mpre on tr ke of the p to th t ıgn t t kes place h rtly aft r the f l ı p ayed ı t the cyl der (see Co ıBUSTION CHA IBER) Ign t t m g ıs th c t lled by the phası g f th fuel ı jectıon p mp wh le th

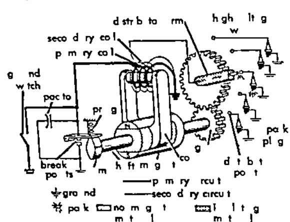


Fig 2 M g t ig t y t m (F m C H Ch t F ld C F T yl d S Ob Th A pl d II E g 5th d M G w-H ll 1949)

firing order of the cylinders is established by the geometry of the pump. In compression ignition engines the fuel burns as soon after ignition as it is able to find air with which to combine, so that less attention need be paid to automatic injection timing control. When control is used, pump shaft position relative to engine shaft can be changed automatically by centrifugal weights and a mechanical linkage.

Sometimes in small engines a premixed charge of fuel and air is ignited near the end of the compression stroke by the temperature of compression. Under these conditions the entire charge, once ignited, burns rapidly since all parts of the charge are equally heated and prepared for combustion. The result is rough, pounding combustion due to the high reaction rate. No precise way exists to control the exact timing of ignition with this method, so that the combustion may occur too early or too late depending upon such factors as the temperature of the cylinder and the kind of fuel being used. Efficiency with such ignition is likely to be poor. [A.R.R.]

Ignitron

A single-anode mercury-pool gas tube operating in the arc region. An ignitor is employed to initiate the arc cathode spot before each conducting period. *See* GAS TUBE.

Ignitron principle. The ignitor is a stationary electrode of semiconducting material, such as boron carbide, which extends into the mercury pool. A current pulse through the ignitor starts the arc at a desired time in each cycle of the ac anode voltage by forming a cathode spot on the mercury surface. Either a thyratron tube or a semiconductor rectifier may be used to deliver the firing impulse to the ignitor. *See* MERCURY VAPOR RECTIFIER.

The tube is nonconducting regardless of anode potential until a source of electrons is supplied to initiate electrical breakdown of the gas within the tube. The cathode spot formed by the ignitor supplies the needed electrons to create an electron avalanche which terminates as an arc. Once the arc has been formed, the cathode spot is maintained by the arc current and the action of the ignitor is terminated.

The ignitron remains conducting until the anode potential is removed and for some microseconds thereafter until all the ions have become deionized.

The repetitive starting technique employed with ignitrons makes possible a short anode-to-cathode spacing, resulting in low voltage drop and high efficiency. In addition, single-anode tubes like the ignitron and the excitron are unique among gas-filled tubes in their ability to carry high overload and short-circuit currents without cathode starvation surge. This results from the use of the excess vapor pressure generated by the overload. The normal vapor pressure is controlled, usually by water cooling, at a value sufficient for best operation at rated load. The combination of a mercury pool cathode and a short anode-to-cathode spacing make it possible for the excess vapor generated by the overload current to fill the discharge space just when needed and then condense on the walls in time for the next cycle of normal operation.

Ignitron types. There are two classes of ignitrons especially designed for different kinds of service. These are the welder and the rectifier ignitron.

Welder ignitrons. This tube is used in pairs connected inverse parallel to operate as ac contactor and control the primary current supplied to resistance welding transformers.

Welding ignitrons are of relatively open construction with little shielding and are designed specifically to carry the high currents encountered in resistance welding. In welding service the anode current wave is sinusoidal, and the current decreases to zero so slowly that the residual vapor blast and ionization present at the beginning of the inverse period is low enough that it does not cause arc back. Furthermore, only the tube that conducts last is subjected to inverse voltage im-

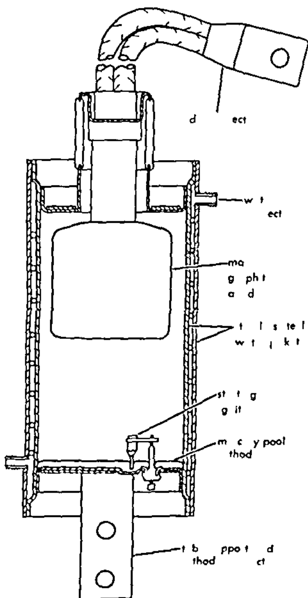


Fig. 1. Sealed ignitron for welder service.

med at ly f ll ng c ndu t on The condit n perm t the u e of tubes w th ut spl sh baffle d ı n ıı g baffle and gr d Th e n tr ctı n of typ l e led ıgn t on for w ld ng ervice ıs shown ı Fig 1

R ct fi r gnıtr ns Th s gnıtr n s g ner lly ed t f x t co rt p we from ac t dc Th m ller t be a e of s al d c n tr ctı n The la ger un t a b ılt n ta ks which ar eith r s uum al d or co t nuou ly acuum pumped

R tıfi r g tr ns ar eq ıpped w th b ffl th pa between th anode a d c thod to pr e t the apo l la t f om thr w ng merc ry d ops ag n t the f f the an de a d t help deı n ze th me ury ap r In the la g r e the an d ro nded by one or mo e gr ds t ınc e se the rate f de nızat n f the sp c adjac nt t the anode d t pr ıd add t al co t ol of th tart f a ode co d ction The n t ctı n f a typ c l h gh-c rr t g tr n f r ctifie e hown ı F g

Firing circuits Ign t r req re a pul e f cur nt of 5-50 amp es n th f rwa d d re tı n from the ıgnitor to the mercury to tart c thode pot Since th gnıtor esı t nce v rıe from a few to seve al hu dred ohms po tı voltage of everal h ı dred olts mu t be mpr ssed n t

The olt ge and current applied to the ı nitor n th re r dır t n must be limited to low v lue to a ıd damage Specı l cırcu ts have been de ı ed to deliver the f rı g p l e t the ıgn tor and pro ıd cont l of the t me of firing

Anode firing cı cuit Th power cır uıt v ltage which app ars betw en an de and cathode just l e f r cond ctı n s u ed t fi e the ıgrıtor ın the rcu t hown ın Fı 3 Thı c rcu t ıs w dely u ed ı ıgn t o conta t r (re ta ce weld ng) *ers ce*

Cap cıto fir ng cırcu t A apacitor that ha b e charg d f m n au ılı ry ac power rce ıs d sch ged thr u h th ıgn tor at the d sıred moment ın the c cl by a thyratron t be n the cı cu t h wn ın F g 4

Mag etic fi ı g cır t Many ıgnitro rect fi a quipped w th m gnet c f rı g to obtain l g r l fe and g eate r lı bıl ty than ıs po ıble with thy t on fir g tube I the c rcuit th capa

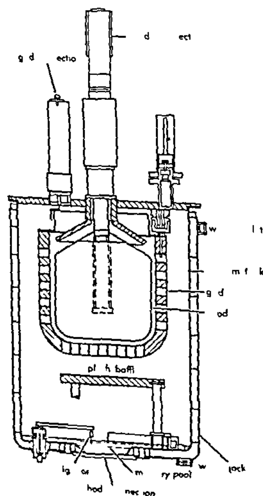


Fig 2 S gl g d ample ect fi ig it (G m ral El)

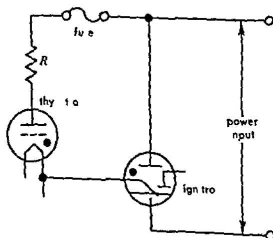


Fig 3 Elem tary n d f g c t

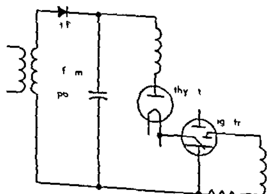


Fig 4 El m t ry t f c p t fi n t ig t

tor is discharged through the ignitor by saturating a reactor which is connected in series with the capacitor

Ignitron tubes and tanks are built in size ranging from 2 to 20 in in diameter Ratings range from 25 to 1000 amperes average per tube at voltages from 250 to 20 000 volts and higher

[C C H]

Bibliography W G Dow *Fundamentals of Engineering Electronics* 1952 J Slepian and L R Ludwig A new method of initiating the cathode of an arc *Trans AIEE* 2(2) 693–698 1933

Ileitis

Regional ileitis is a sharply demarcated inflammation of the lower portion of the small intestine Actually other portions of the small and large intestine may be involved so regional enteritis or regional enterocolitis may be preferred terms

The disease is marked by intestinal obstruction pain cramps diarrhea and constipation There is often associated weight loss or anemia Late in the disease after a long but often vague history the bowel appears thickened and firm and has a nodular mucosal lining which shows variable ulceration and inflammation Adjacent segments may show little or no change

The cause is unknown but faulty protein absorption psychic factors and abnormality of lymphatic drainage have been implicated by various investigators Although regional ileitis is found most often in young adults no age group is immune

The clinical course is typically erratic but progressive in most individuals Neither medical or surgical treatment offers a guaranteed cure because extension to previously unaffected bowel segments may occur

In contrast to regional ileitis ordinary ileitis is any inflammation of the ileum from specific causes such as trauma or infections such as tuberculosis typhoid fever and dysentery *See* INTESTINE INTESTINE DISORDERS OF [E C S T]

Illite

The term illite is not a specific clay mineral name but is a general term for the mica type clay minerals It is commonly used for any nonexpanding clay mineral with a 10 angstrom *c* axis spacing *See* CLAY MINERALS

Illite clays are used for the manufacture of structural clay products such as brick and tile Some degraded high plastic illites are used for bonding molding and *See* CLAY COMMERCIAL CLAY PRODUCT ARCHITECTURAL

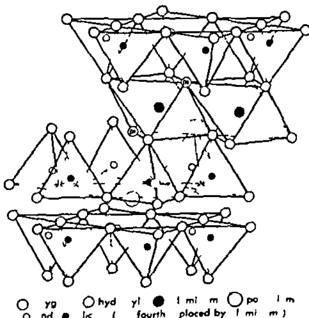
Structural characteristics By definition all illite have the mica type structure The basic structural unit is composed of two silica tetrahedral sheets with a central octahedral sheet This unit is essentially the same as that of montmorillonite except that there is always some replacement (15% ±) of silicon by aluminum in the tetrahedral sheets This substitution results in a charge deficiency which is balanced by potassium ions between the illite unit layers The stacking of adjacent illite layers is such that the potassium just fits and is always surrounded by a total of 12 oxygens thus balancing the structural charge and binding the layers together without the possibility of expansion (see Fig 1) Illites may be either dioctahedral or trioctahedral depending on the population of possible octahedral positions They differ from well crystallized micas in that they exhibit less substitution of aluminum for silicon resulting in a higher silicon to aluminum molecular ratio

Nonstructural characteristics The size of naturally occurring illite particles is very small yet they are larger and thicker than montmorillonite particles and have better defined edges

The illites have a moderately low cation exchange capacity (20–30 milliequivalents per 100 grams) It is primarily due to broken bonds but lattice substitutions may also be a cause in poorly crystallized varieties The rate of the exchange reaction is likely to be slow since a small part of the exchange occurs through partial replacement of the firmly held interlayer potassium ions

Dehydration curves for illites show the presence of a small amount of interlayer water which is lost below 100 C The OH lattice water is lost between 300 and 600 C Following the loss of structure between 850 and 950 C spinel and mullite phases form prior to fusion at about 1400 C

Occurrence Illite is a common product of weathering if potash is present in the environment of alteration It is a frequent constituent in many soil types and may form in soils under certain conditions as a consequence of the addition of potash fertilizers This is possible because illite has the ability to fix potassium Much illite in soils loses its potassium through leaching and becomes degraded On the addition of potassium to such ma



O yg O hyd yl ● l mi m O po l m
O nd ● lc (fourth placed by l mi m)

D ag mmat c sk tch of the structu of Ill te (F om R E G m Clay M l gy McG aw H ll 1953)

t r l k goe back ı t these normal po t on a d the ıll te eb ılt *See* SOIL

Ill te ı common ı rec t sed ments and ıs par t larly ab nd nt n d ep- a clay It probably forms f m mo tm rıllonıte and other m eral d ı g marine d ge es B cause f t stab l ty ll te fte fo nd ın anc ent ed m nt It ıs the d m nant clay mine al n many probably m t h les that ha e been tud ed S DIAGE ESIS MARI E EDIME TS SHALE [F M W R E CR]

Illuminance

A te m e p e ıng th lum n s flux fall ng on a rfac Th word h s been prop ed by th Col ımetry Comm tt e f th Opt al Soc tv f Am c to epl ce th term ll ım natı n Th def ıtı n ar the same

Th ymbol of ıll m natı n ı E and the qua t ı $E = dF/dA$ wh r A ıs the a e f tl e ll mınated u f ce and F the lumın us flux S ILLUMINATIO PHOTO IETRY [R C.P]

Illumination

I a g e al en e the sc n e of th appl atı n of l ght ng Rad t on ın th ange of w velen*th f 0.38–0 6 m c n (μ) produ es the ı ual ffect mm ly lled l ght by the resp nse of th a er age hum ye f r normal br ll n levels Illum atı n eng e ng pert s t the ur e f light ıng a d th d gn f l ght g y tems which d trıb t l ght t ffect a omfort bl nd ffec t e ı nm t fo e g

In pe fic q a t t tı e llum n t on (met mes alled llumın nce) the c mb nat on f th patı l d n ty f rad ant p we ec ed at rf and th ffect e ess of th t radı t o ın p odu ı g a u l eff t S ILLUMINANCE

Luminosity curve of human eye A standa d espo e f th h m ye to rad tı n at normal l ıll n le el wa tabl h d by ı t rn t o al g eem t 1924 by La Commı n Inte nat o- al d l É la g th o gh the f nct n kn wn a th CIF al es of bıl ty (Th lett s ICI f th E gl h m a lso ed) Th d nate f th f n t sh pl tted ag st tl w l ngth f r d tı F g 1 nd are t b lat d ın th t l l Th d n t mm ly alled th

Rel tive l ml osıty factor (val of ıty at 0 554 wavelength)

W e le g h,	F ctor	W e l th,	F	W e l gth,	F to
0 38	0 00001	0 51	0 503	0 64	0 1
0 3	0 0001	0	0 10	0 6	0 10
40	0 0004	0 53	0 86	0 66	0 061
0 41	0 001	0 54	0 9 4	0 6	0 03
0 4	0010	0 5	0 99	0 68	0 017
43	0 011	0 .6	0 99	0 69	0 008
44	0*3	0	0 9	0 0	0 0041
4	0 038	0 8	0 8 0	0 1	0 00 1
4	0 060	0 9	0	0	0 0010
0 4	0 091	0 60	0 631	0 3	0 000
48	13	0 61	0 503	0 4	0 000
4	0 *08	0	0 381	0 5	0 0001
.0	3 3	0 63	0 6	0 6	0 00006

Fg 1 Lum ty curv f th h mo y (F m W B B o t Ill mn t E g g 2d d M G w H ll 1953)

rel t v l mınos ty factors See LUMINOSITY FAC TOR

At th esh ld level of e ı g th spectr l re- p e function f the eye ı hıfted toward l wer wavel ngth This effect ıs known a th Purkı je effect

Photometric definition Illumınatı n (or ıllu mın nc) ı the d ns ty of radiant p we ıncide t up n a ece ng s rfa e ev lu t d through ut the pe trum ın term f th ICI val es of ı ıb lıty F r a l e-spe trum compon nt of ırradı tı n a ımpl multıplicatı n of the ırr d atıon compo- n nt G and the valu f relatı e luminosıty factor v taken t the pr per alue f wavel ngtl ı yıeld the omp nent ıllumınat on F r co tınu us- p c t um ı radıat o G ı function of wavele gth the ef re th p odu t of the two functı ns v and G mu t be ınt grated St t d mathematıc llv for a c mb n tıon of l ne spe t a and continuo s pec trum ource

$$E = k \sum_i v G + k \int_0^\infty v_\lambda G_\lambda \, d\lambda$$

whe e G ı the ırrad t n due to th ıth ompo n nt f the l ne p ct a s the elat e l mı os- ıty fa t r t wa el ngth c rre pond ng to th w elength f the th omp n nt ır dıatıon n ı the numb of mponent l ne pe t a r dıat on G ı the spectral ırrad atı n f the ont n u spect m t λ wavelength v ıs the rel tı e lumı o ty f t t the rre p nd ng wa elength nd k ı a co tant equal to 680 l mens/watt

Th tandard upon which all q ant tatıv n ts n th field of llum n t on are based the bright n r lum na of a black body rad ato at the freezıng poı t of pl t num (2042 K) The bright n h s b n ta da d zed by ı t rnat onal agree me t t 60 c ndle / m² (or 60π l mberts) This alu t g th r w th Pl ck equ t n fo the r d t n d ty when evalu ted ın te m of the lum nos ty fun t on y elds th co stant k of 680 lume s/watt Se LAMBERT LUMINANCE

Th lum n ı the un t f lum n u fl th t re lt wh n r d nt pow r ı evaluated th o gh th

luminosity function. Any one of several units of area may be used to express the density of this luminous flux or the illumination. In the English system the unit of illumination is the lumen/ft². The term foot candle was coined in earlier evaluation techniques and probably will continue to persist in the terminology. The lumen/ft² and the foot candle are identical units. See FOOT CANDLE; ILLUMINANCE; LUMEN; LUMINOUS FLUX; LUX; PHOT.

Light sources. Nature's source of radiation, the sun, produces radiant power on the earth extending from wavelengths below 0.3 μ in the ultraviolet region to well over 3 μ in the infrared region of the spectrum. The sun's spectral radiation per unit of wavelength is greatest in the region of 0.4–0.9 μ. The response of the human eye is well matched to this range of wavelengths. See SOLAR RADIATION; VISION.

Oil flame and gas lighting were used before the advent of the electric light, but since about 1900 electric energy has been the source of essentially all modern lighting devices.

Incandescent lamps. These electric lamps operate by virtue of the incandescence of a filament heated by electric current. The filament usually is composed of tungsten and is contained in either a vacuum or inert-gas-filled glass bulb. See INCANDESCENT LAMP; INFRARED LAMP.

Vapor lamps. These operate by the passage of an electric current through a gas or vapor. In some lamps the light may be produced by incandescence of one or both electrodes. In others the radiation results from luminescent phenomena in the electrically excited gas itself. See ARC LAMP; VAPOR LAMP.

Fluorescent lamps. These are usually in the form of a glass tube, either straight or curved, coated internally with one or more fluorescent powders called phosphors. Electrodes are located at each end of the tube. The lamp is filled to a low pressure with an inert gas and a small amount of mercury is added. The electric current passing through the gas and vapor generates ultraviolet radiation, which in turn excites the phosphors to emit light. If the emission of light continues only during the excitation, the process is called fluorescence. If the materials continue to emit light after the source of excitation energy is removed, the process is called phosphorescence. Phosphors for fluorescent lamps are chosen to accentuate the fluorescent action. See FLUORESCENT LAMP.

Reflection and transmission. The control of light is of primary importance in illumination engineering because light sources rarely have inherent characteristics of distribution, brightness, or color desirable for direct application. Modification of light may be provided in a number of ways, all of which may be grouped under the general topics of reflection and transmission. Reflection from a surface and transmission through it each may be classified according to their spatial and spectral characteristics.

Spatial characteristics. Spatially a surface may exhibit reflection conditions ranging from a regular or specular reflection to an ideally diffuse characteristic. Similarly, transmission may range spatially from complete transparency to an idealized diffuse transmission.

Figure 2 illustrates the extremes of specular reflection, such as would be obtained from polished metal or silvered glass, and an ideal mat finished surface possessing microscopic roughness of minute crystals or pigment particles. The specular reflector gives a direct image of the source with the angle of reflection equal to the angle of incidence. The plot shown for the diffuse reflector is the small-area intensity distribution curve; it exhibits a cosine distribution in the idealized case.

Practical surfaces possess spatial reflection characteristics intermediate between these ideals, particularly at the diffuse end of the range. Typical distribution curves are shown in Fig. 3. In all of these illustrations the light source is small. Figure 3a demonstrates that even with the best practical mat surfaces, such as dull finished metal or those painted with flat paint, the location of the source of light has some light influence upon the intensity distribution as evidenced by an irregularity of the cosine distribution of intensity of the small area of the surface. Figures 3b and c demonstrate the pronounced influence of the location of the light source upon the intensity distribution for surfaces covered with semimat material such as

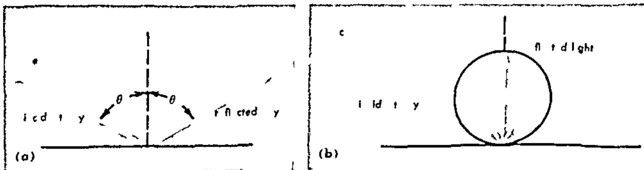


Fig. 2 Ideal reflectors. (a) Specular. (b) Diffuse. (From W. B. Boast, Illumination Engineering, 2d ed., McGraw-Hill, 1953)

t n fin h p i r F gure 3d llu t at a m x d r flecti jh n m n n e lt n wh n a diffu ing u f e i o erla d th a urface p ing heen

Spat l char te t f t an m i n r llus- t ted F 4 F g r 4a hows regula trans- p r nt tra m on i h a o urs w th l ar gla r pla t F g r 4b h ws the diffu tr ns- m tf at w uld r ult with a d al z d d ffu ing mate ial I F 4a a refr t of the trans- par t imag curs b t th angles θ and θ ar

P a t al t n mi on mater al p o e patial tr n m h t r t i t rmedi t betwe n th e d al d h b t nten ty d tributi n rves ll t ated by Fi S Figu e 5 d mon tr tes that a p f ct nten its d t but o t t lta n de with l d pal m lk gl s m t i L A m r d e t tr n m n i h wn in Fig 5b f a fla l ed pal gl m di m n wl h the m j r t of the ba m t l i cle r gla s S nd l d f ted gl mate l s mu h l d ff i a d the lo ti n f th light u ce g tl i fluenc s th nte t d tr b ti n curve (Fig 5 a d d

Sp t l h t t If a h m eneo ad ti n (w l gth λ mp nge up n u fa e th flect ha a t i t c o th t an m n ha t t ll res lt geom tr c ll a e d ng t th p t i n d r t f the p d g t n The m gnit de l t t) power d n ty r fl ted or tr mitt d to th t d defi d a the p c t l fl t n f t ρ or the p t al tr m s- s on factor re pectively Thus $\rho = J/G$ and $= J/G$ whe e J is the reflected pectr l mis- ion at wavelength λ J is the tran m tted spec tr l emi i n at wa ele gth λ a d G s the spe tral i radi t on at wa length λ

A d ce f r mea ur n ρ or s called a spec tr ph tom t r Compar n of J r J with G (r its e tial equ vale c) may l e ac ompl hed by i ual ph t electr c meth d of photom etry *See* PHOTOMETE

E ther ntinu s- r l ne-sp ctra s urces of ir r d ati n m y con t t te a practical s urce of rad a t p w r dens ty The resulting s c nd ry source of adia t power density J or J will be modified c mp red w th the o g nal depend ng upon th spectral fl ction r t a m on character tic f the reflecti g or t ansmitt ng mate ial

An e alu tion f J r J ing the elative lumi n s t fa t r s may be effe ted for the econdar ource f radi nt p wer den ty in the am m n ner as i done f r cid nt adiant power den ity nd t s B th l ne- nd c ntin ous spe t um ef fe ts m y be in luded as dem nstrated f r the eval t n f th illumination Th e aluation of the r fle t d tran mitted lum nou fl d n ity yi lds the lum ance ymb l d by L f r the re fle t n f and L for the transm tt g u fa Th fun tio al operati n are h w g aphi c lly th r of curve of F g (for the r fl ti re ult ng f om a c nt nu s- pect um u e The rati f L r L t th llum nat n E e lt n $\rho = L/E$ and $\tau = L/E$ whe e ρ s the

Fig 3 Typical flectio h ct t (a) P ct l st l D hed rv i ( ) d (d) ll t te d l o- ma rf (b) Sem m t rf ( ) S m m t rf larg ngl f i id (d) P l ne- m l d d but (F om W B B f Ill m t E g g 2d ed McG w H ll 1953)

luminosity function Any one of several units of area may be used to expre s the den ity of this luminous flux or the illumination In the Engli h system the unit of illumination i the lumen/ft The term foot candle was coined in earlier evalua tion techniques and probal ly will continue to per si t in the terminology The lumen/ft and the foot candle are identical units *See* FOOT CANDLE ILLUMINANCE LUMEN LUMINOUS FLUX LUX PHOT

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Practical urfaces po e s patial reflection characteri tics intermediate l etween the e ideal particularly at the diffu e end of the range Typi cal di tril ution curve are hov n in Fig 3 In all of the e illustration the light ource i mall Fig ure 3*a* demon trate that even with the l e t practi cal mat urface uch a dull fini hed metal r tho e painted with flat paint the locati n of the urce f light ha me light influence up n the inten ity di tril ution a evidenced l y an irregu larity f tl e c ine di tril uti n of inten ity of the mall area f the urface Figure 3*b* an l c demon trate the pr n unced influence of the l cation of the light ource upon the inten ity di tril ution for *surfaces co ered with emimat material uch a*

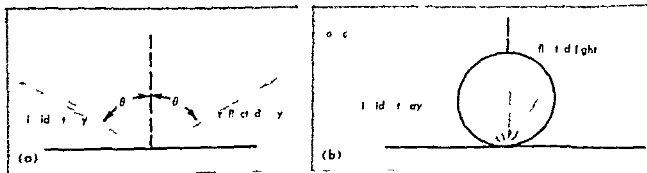


Fig 2 Ideal efl ct on ( ) Spec la (b) D ff (F m W B Boa t Ill m t o E g ee g 2d ed McG aw H ll 1953)

refl cti n fa tor of the urfac and i the transm on f ct r of the mat l The reflect n and t a m on fa t s are dep dent up the ource of illumin ti n a well as th spect al cha cter s ti s f the rfac or the tr n mitting med um Su h fact r a e frequently publ hed f r tungsten filame t l ght and ar u eful as gu des and i d ca t f magnitude if th our es f illum nati n d n t d iate too greatly f om th s pe tral di trib ti n

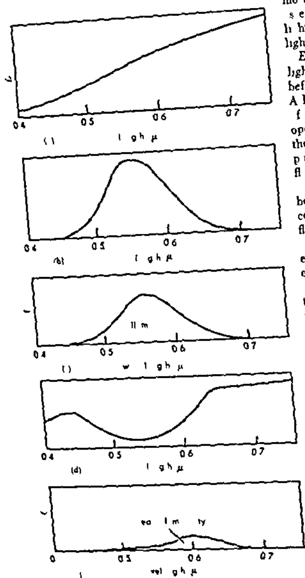


Fig 6 Th proc of val t g l m f flect g surf f eval t ng th ll m t ( ) Spectral irradia io G curv (b) R l tive luminosity f ctor rve ( ) C rve f C Ill m t is he ea und this curve th i t grat f C d) Spectral reflectio f ct ρ rve ( ) C rv F ρ G (mina is th ea d th curv the integ ion ρ G (F m W B B st Ill m o Enginee ing 2d d McG aw-H ll 1953)

Light control methods Th character of th efle ting urf ce or transm tting material dete mine the deg e of l ght c ntrol pos ble If a li ht ray is r flected r tran mitte l diffu ely the hape of the refl cting r tran mitting urface i of l ttle importan e alth ugh its ze may be of g eat importance A lar er diff e urface will redu e the br ghtne s of the primary s rce If a light ray s r flected fr m a pecular urf ce more accurate cont ol f th l ght can be effect d

Pa ab l c efl ctors Th e r probably the mo t u eful of all r fl ct r f rms The rays eme e s ent ally p rallel f om such a reflecto if the li ht u ce is pla ed at ts focal point Se r h light u e p rabolic mirr r refl ctors

Ell pti eflecto s A relati ely large amount of light may be made t pa s thr u h a mall opening bef pre d n out b u ng an ell pti reflector A li ht o e i placed at ne of the focal p ints f a nearly ompl te ll pt cal reflector A mall openi g is placed t the nd focal po nt where the light i focu d Such a de ign is u ed for the p n h le spotl ht F r further d cu i n of r fl ctor *see* PROJECTOR (LIGHT)

L ns c trol Refraction of l ght rays at the boundary between gla s and air may be u ed to cont ol tr n m tted light in a manner similar to refl ct r o t l S mpl thick lense may be cut w y if the ut away p ece is duplicated n the new equ valent s rface Sli ht ir e ula it es in th fi ld of the l ght be m o ur Th e may be of l ttle n eq enc fo ar hli hts or fl odl ght but they would be undes rable for h gh qu lity p ture p oje tion *S e* LE S OPTICAL

Pola izat on of light Light ays mitt d by common sou ces may b c n de ed s wa e i b ti g at ll ngl plan s at ri ht angles to th d ect n of the ay As they pa thro gh me ubstanc s o a r flect d f m p c la urfa es, part cularly t c tain a gl s wa e c mp ents i m d e ti n a absorbed m r than th e i othe d e t n S h light sa d to be p la iz d Pol i ed light m y be cont ll d by a tr mit t g s ti n f polari g mater al Wh n the ab rbing s tio or ted t p rm t pas age of the p la zed l ght m nim m c nt ol is xerc ed If the ab o li g se t n is t t d 90 th polar d l ght i s enti lly completely ab orbed Be c u l ght r flect d fr m w t r or p cular r f s s h ghly pola z d glar f m u h so rces eff t ely trolled by pol r z d sungl s r am a filte P la iz d l ght i n ed al o fo de te ti n of tr s a d d f cts in gla r plastics Th train d are s app s c lo fri tl m t i l *S e* POLARIZ D LIGHT

Interior lighting design Att nm t of a com f table i l o ment i the lt m t go l o i t r r l ght ng de ign Th s eq e a dequat di tr bution of illum at o d cont ol of brigh es f ll i bl u fa t a o d xce i e con tra t Th ad q ate d t b t n of illum ti requi that fficient n mb f l ghti

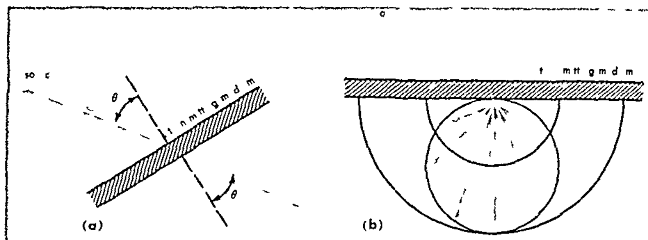


Fig 4 Ideal tra sm ss on cha acterist cs (a) Specular (b) D ffuse (F om W B Boast Ill m at o Eng neer g 2d ed McGraw H ll 1953)

Fg 5 Typ c l t a m ss on cha acte t cs (a) Sol d opal glass (b) Flashed op l glass ( ) Sa d blasted glass (d) Sand blasted glass with cide t l ght at 30 f om pla e at rface (F m W B Boa t Ill m at o E g ee g 2d d McG aw H ll 1953)

er l l ght ng wh e h gh les l of illumi ati n is d rabl o an solated ta k Local l ghting that does t uppl m nt ge ral l ght g u ually doe t perm t conform nc w th the l m tati ns n b ghtnes c tra ts for nt rior light ng de gns

Exterior lighting design The btt me l ght g of t tr r at a rves many u eful purpo es Su h l ght ng e te d int the fi lds f ad ert ing and rec e t l p r u ts as well a t l t r an fi ld i h th l ght ng f nd tr l yards pa k ng areas a rpo t treet a d h ghw ys The *IES Light g Handb ok* a d m ny t xtbooks t eat in d ta l ma y f the e pec al zed appl at ons.

Automobile headlamps H adlamp u tw beam of d ffer nt ch ra t r t under the on trol f th d The a m g nd i t n ty f n beam d gned t prov d di tant ill mi at n Th tl r b am i med l w enough and in ch di ect o t p ev t glar f r coming dri er

Sealed be m h dl ght ha e been d n e b t 1940 Wh n filam nt b rns t the *enti e* l mp i epl d th s re t ring th parabol c reflect a d nd t of alignm t of the l g t sou e bett tha was p ble f r a epa ate lamp i p rman t flecto

Recommended standards of illumination Illu m n t les l ha e b e t ll hed by the Illu m n t ng Eng eri g Soc ty t b g all al ta k t th am lev l f ib lity f n m l ol rs Som l t k m e a d than th r and h gh r ll m t o p o de a on pe t ng f t r n b ng ng h ta k t a s t f t y lev l f b l t St dard est b l h d t ly f r nte i r l ght ng d gns but lso f r t r o s t m l d g rec eat onal l ght g F r t l l l mmended illum t n les l lt efer li ted in th b bl gr phy

Colored l ght Th great t p ect n i col r pec fi at obt ned b th u f th p t al rves f t t a el gth f th d at o If wev l r i al n d t o it h s b l d that y l r m d p l ompl p tral mpo nt m be m t hed ally b p p r t g th p pe ly h mpon t r dia i Th l t m gn tu d f thes th e m r t d t r lled th trich omat oeff i nt f th l r Oth d gn t f d m t w l ngth d pe tr l p ty m y be l t ed l n f m thes tr h mat oeffi e ts

[W B B]

Bibliography C. L. Am k *Fl* s nt *L ght* ... d ed 19 W F B w *l ght* ... *d Ill m t g E g* r g 3d ed 19 1 W B Bra t *Ill m t n E gin g* d ed 19 3 Illum t ng E gi ee g Soc ty *IES L ght g H db ok* 3d ed 19 9 A F Kn ll n *d d H dbook f El t l E gi* 9th ed 19 J O K h nt hl *El t i Ill m na t* l ed 19 1 l H Moon a d D E Sp r *l gh g D g* 1948 H P d a l W A D l M ed i *El t f E g H dbook* 19 1 *h ed* 1949 H M Sh p *I t od t t Light* g 19 1

Ilmenite

A m neral having compo iti n $FeTiO_3$ and cry tal l zing in the h x gonal y tem Ilmenite i found n cry tal that are tab la parallel to the ba al plane with rh mb hed al t ncat on but u ually m s e Th hardn s is 5 5-6 (M hs cal) and the pe ific gra ty s 4 7 Th lu ter i m talli and the c l r i r n black Ilmenit s an acce ry m neral n igneou o ks and n ome ba ic rocks i f und n la ge m s es res ltin from magmatic segr a t n i wh h it may le i tmately a c ated with magnet te It i found in cry tals n the Ilmen Mountains, Rus a and n la g *q antiti s at* K age Norway a d Bay St Paul and Allard Lak Quebec In the Un ted States it i a ciated with the magnet te depo it f th e Adiro dack r g on a d i mined as an re f titanium at Tahawa New Y k *See* TITANIUM [C.S HU]

Image acoustical

If point sou e of o d *is placed* on on id f n xte d d eflect ng urface *it may* be co id red t ha e an imag " at an eq i alent d tanc on t th r ide of the s rf ce al ng a perpend cular p oje t on nalog u t th f r lia opt al ma e (s e IMAGE OPTICAL) The ff ts of r fle ting urfa es on a *ou ti w ie freq* ently ca be p e *d ted by the* u f u i im ges A sou ce i f ont of a ery r fl ti wall (f r example plast r co c t and ma ry reflect 97 99% of i c d nt *nd energy*) will h e an image of trength alm t eq al i that of th ou ce ib at g in *pha e th the* ur T obta the t tal effect at any p t *du to the* mbi ed act on of a urc a d su h r fl ti g u fac the *effects du t th* u c it If d noth r ou e of equal t ength placed at the mag po nt a e dded If there i a ec d flect ng u f e pres t th o-c ll d fi t-o de *m g* w ll h e n ima e called the co d-order im g of the rce at an quiv le t di t nc n th th id f th nd r flecting i f S m larly n image f the e ond-ord mage id t b th d rder mag *nd* o on Alth gh th *method* is p ect e nly when th fle ti g s rfa e i o ab orpt t i ften of n d rabl h lp n in est gati n of th act on of sound wa es n ooms *S* ARCHITECTURAL A OUSTICS [C M H]

Image optical

A pt cal im ge i tl e m g f rmed b the l ght rays f m elf l min s o a llum nated object th t t rse an pt cal y t m Th m ge s *sa d* t be r al *if the l ght* ay con erg to a focus on th im g de and rtual if the *ra*y seem to m f m a po t with n the in trument (s e ill tr t n)

Th pti l m g of bject i g n by th l ght d trib t n th m g plan mi g fr m a h p nt f the object t th mage pl e f a pt l ystem The id al m l a p t c d ng t geom t al pt s obta ned when all rays

sources be installed in a manner that produces an adequate level and a proper distribution of illumination. Brightness is controlled by adequate surface reflection or transmission areas associated with the lighting sources and with proper reflecting surfaces within the room itself. Control should ensure that the brightest surfaces of the room are not more than three times the brightness of the work and the brightness of the work not more than three times that of the darkest surfaces in the room. When such brightness ratio limitations are satisfied, glare will be absent and a satisfactory visual environment is achieved. A proper application of color in the interior enhances the over-all appearance.

The function of a building greatly influences the manner in which lighting is applied. A particular visual task may require a certain level of illumination, but the lighting design is also influenced by the economics, appearance, and quality of desired result. For example, application techniques are designated as industrial lighting, commercial lighting, and school lighting. Certain application experience and consumer acceptance assume importance in the methods of achieving the level of illumination and control of brightness contrasts. The *IES Lighting Handbook* treats in detail many of these specialized concepts.

Location and spacing of luminaires. Many interior lighting designs utilize general lighting to distribute luminous flux throughout the room on an imaginary working plane, which is usually 30 in above the floor. To accomplish a reasonably uniform illumination on this plane, certain limitations in spacing between luminaires and spacing between luminaires and walls must not be exceeded. The height of luminaires above the plane may be an important factor for some interiors. For indirect-type luminaires the distance from the ceiling to the luminaire must provide a proper distribution of light over the ceiling. *See* LUMINAIRE.

Room coefficients. The shape of a room influences the fraction of the emitted luminous flux that will be received on the working plane. Equations and empirical tabulation have been developed to classify rooms according to their shape. Large broad rooms are more efficient than small or narrow rooms for transferring luminous flux from the luminaire to the working plane, particularly if the reflection factor of the side wall is low.

Lumen method of illumination design. This empirical method of design gives the average illumination on the working plane for a particular number of luminaires arranged in a symmetric pattern in a room. The illumination that may be expected to be maintained in the room is

$$F = \frac{N \phi_L K M}{A}$$

where F is illumination in foot candles (or lumens/ft²), N is number of luminaires, ϕ_L is initial luminous flux per luminaire in lumens, K is coefficient of utilization, M is maintenance factor, and A is area of room in square feet.

Tables of the coefficient of utilization are obtained empirically. Usually these tables pertain to a particular luminaire. The coefficient of utilization is a function of the room coefficient and the reflection factor of principally the ceiling and side walls. Also called the flux of light method, this was originally designed as a component method whereby the candle power distribution curve of any luminaire could be resolved into three component curves and each calculated according to an equation similar to that shown. However, modern use of the method is principally through coefficients of utilization for each particular luminaire.

The maintenance factor M is a number less than one to account for lamp darkening and the collection of dirt within the luminaire, which reduce the illumination emitted from the luminaire.

Interreflection method. The interreflection of luminous flux within a room is accounted for in the empirical data of the lumen method. An exact mathematical calculation of the distribution of luminous flux within rectangular rooms becomes extremely involved. Various simplifying assumptions, however, permit an approximate solution for both the illumination upon the working plane and the brightness of various surfaces within the room. Tabulations of calculated data for the normalized illumination and brightness for interiors of various room coefficients and surface reflection factors are published in some of the references given at the end of this article. Conformance with the 3:1 or 1:3 brightness ratio criterion for a comfortable visual environment becomes a standard checking procedure in the application of the interreflection method.

Luminous architectural elements. The original emphasis in the lumen method was upon discrete luminaires arranged symmetrically within the room. The development of the interreflection method of design presumed surfaces of initial brightness on ceiling, walls, and floor as the sources of light within the room. Ingenuity in the application of both methods permits them to be applied both to designs involving luminaires within the room and to designs incorporating many types of luminous architectural elements, such as louvered ceilings, luminous ceilings, and other systems of lighting.

Natural lighting. Daylight may be an important factor in building design. For comfortable visual conditions, any openings for the admission of daylight are planned in position, size, and shape as carefully as any other part of a building. A window can be treated as any other type of light source and included as a part of the illumination and brightness design according to the conventional design procedure. It is usually necessary to provide electric lighting systems for the times of day when the daylight is not available.

Supplementary lighting. Local lighting such as spotlighting is frequently used to [illegible]

er l l ghti g whe e h gl level of illum at n i d able n sol ted ta k Local l ght ng that does n t ppleme t g ne al l ght g usually d n t perm t c form n with the l mitat n on bright es ntra i f r i t ior l ghting des gn

Exterior lighting design The nighttime light ng of ter r a e rve many u eful pu po e S h l ght ng t nds t t the fi lds of d erti g nd recreati al pu it well utilita i n fields h th l ghting f ind tr al y d p rk g a as, r y rt tre t nd h hway The *IES Lighti g Ha db ok* a d m ny textb oks tr at in det l m ny f these sp cial z d appl at ns

Automobile headlamps Headlamp u e two be m f diff r nt ha a t t c u der the c n t l f th dri e Th a mi g nd inten ity of ne be m i de ig d t pr d d t nt ll m n t on The the beam t aimed low ough a d in uch directi n t p event gl r fo c m g d r

Sealed beam l dl ghts ha e bee u ed sinc abo t 1940 Whe a f lam t burn ut the ent e lamp i r pl ced th e t ing the p ab li re flect r a d c d t on f alignm t f the light sou e bett r tha was po ibl f r p r t lamp in a perma e t r fle t

Recommended standards of illumination Illu m t I l h b e tabl hed by the Ill m t g E gne r g Soc ty t b g ll t al ta k t th m l l of i bil ty f n rmal b n Som n l ta k a m r d o th n th a d high ll m nat s pr vid a om pen ti g fa t n br ng g h ta ks to at s f t ry l l f i b l ty St d d re tab l hed n t nl f r nt r r h bt ng d g b t lso f t ri v t m t cl d ng ec e t on l l ght ng F tables l ec mm ded ll m t n les l lt f n es l t d n th b bl gr phy

Colored l ght Th g t t p e n c l r per f t hi d by th t of th p ct l nes f n t f wa l gth f th r d at n ll wes f ual n d ati n it h s b e l d th t y l r m de p t mpl p tral mpo t ma he m t h d i lly by p p t i g th ee p pe ly h ompone t rad t Th t t m g it des f thes th e m po t d t n a lled the t hrom t c oeff t f th f Oth d g at n f d m n t w l gth d pect l p r ty m y be ob t ed lso f m thes t h mat ffi nts S C o [W B B]

F ll g rh C. l Am k Flu nt L ght g M l l d 1937 W F B w Light f k m d Ill m t g E g g 3d ed 1 1 W B B t Ill m t F g n g d ed l 1 3 Ill m t g F g ee g Soc ty IES L ht g H dbook 3d ed 1 9 A E Kn wlt t d H llbook f Fl tri l E g 9th ed 1 J O K t l hl Fl t Ill m na d ed 1 l t H Moo nd D F Spen L ht g D z 1948 H f nd t d W A D l M ed t Fl t l F gi H dbo k l l 1h ed 191 H M Sharp Int od t t L ght g 19 l

Ilmenite

A m neral hav ng comp tion $FeTiO_3$ and cry tal l zing in the h xag n l sy tem Ilmen te i found n ry tals that are tabular p rallel to the ba al plane with rh mb hed al t un ati ns but is u ually mas s e The ha d es i 5 5–6 (Moh cale) and the pecific gra ity i 4 7 The lu ter s m tall c and the colo i iron bla k Ilmen te i an a c ory m i eral

igneous ro k and in om l a i o k i f und i la ge ma es re ulti g from magm ti seg ega t n i wh ch it may be ntimately a c ated with magn tite It i found n cry t l in th Ilmen Mou tains Ru a nd in large q ia t ti at K ag Norway nd Bay St Paul and Allard Lake Quebec In the U ited States it is a oc ated with th magn tite d p ts f th Ad ronda k r g and is m n d as an o e f titanium at Tahawa N w Y rk *Se* TITANIUM [C H U]

Image acoustical

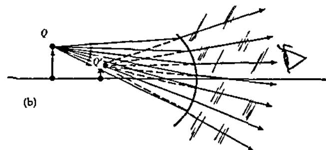
If po t sourc f und i placed n n d of an te d d r flect ng f t may be c n d red t h a image at an equ val nt di ta ce n th th r d of the rfac al ng a pe pendic l r pr j t n anal g u t the fam li r opti al mage (*e* I AGE OPTICAL) The ff ts of reflect g u face n ac t c waves freq ently an be p d ct d by the u e f s ch imag A u e in f nt f a ery reflect wall (for x mpl pla t r c n c ete a d ma ry r fl ct 97 99% of i d t und e y) w ll ha e a image of t ength alm t eq al t th at of the u c ib ati g in ph e w th the ou ce To obta n the t tal effect t any p i t due to th mb n d acti n of a urc and such a efl ting u fa e the ffect due to th so rce t elf d ther sou e f eq al str ngth pl ed t th imag po t e added If th re i d reflecti g su face pre ent th alled fi t d r mage will h an im ge alled th cond rd im of the i rce at an qu al nt d ta ce o the oth r de of the d r fl t ng u f e S mila ly an imag f the e ond-ord m ge i a d t be a th d-o de mag d o on Alth gh th m thod p e i e ly when the re fl t ng fa i n b rpt v r i oft n f derabl help in i vest gat s of the acti n f sou d w es in oom *S* ARCHITECTURAL ACOUSTICS [C M H]

Image optical

An opt cal im ge th mag f rm d by th l ght r s from a self l m u n ill m at d obj t that tr se n pti al y t m Th m g s s d t be al f the l ght y n g t fo us n th mage il a d rt al if th rays em to om f m a po t withi the in trume t (ee Il s t t)

Th opt al mag f n bje t s gi n by the light d t ib t in th m ge plan m g f m ch p i t of th object at th imag pl ne of n opt l s t m The d l im g of point a c rd i g t geom t ical opt s bta ned when ll r ys





(a) Real image Rays leaving object po nt Q a d pas ng through th efract g su f ce separat ng med a n a d n are b ought to a focus at the mage po t Q (b) V rtu l mage Rays lea ng Q and refracted by the concave spherical su face sepa at g n a d n ap pear to be com ng from the v rtual image po nt Q As they a e d ve g ng they ca ot b focused at any point (*Mod fed from F A Jenk s a d H E Wh te F ndam tal f Opt 3d d McGraw H ll 1957*)

from an object point unite in a single image point However diffraction theory teaches that in this ca e the image is not a point but a minute disk The diameter of this di k is about 1 22λ/A where λ is the wavelength of the light considered and A is the numerical aperture the largest cone angle on the image side multiplied by its refractive index (which is usually equal to unity)

Aberrations From the standpoint of geometri cal optics if this most desirable type of image formation cannot be achieved the next best objec tive is to have the image free from all but aperture errors (pherical aberration) In this ca e the light distribution in the image plane i till circular re eml ling the point image there is a true co *ordination of bject point and image although the* image may be slightly un harp If the aperture error are mall and the image i viewed from a di tance such an image formation may be very ati fact ry

Asymmetry and def rmation error may l e very di turl ing if not held in che k l ecau e the light di tril uti n of the image of a p int in this ca e ha a decidedly unde iral le l ape

When the image of an axi point i con idered tl e rav through any fxed aperture circle converge to thi axi point For thi type of imagery the t rm l alf harp image will l e t ed A mall ol ject at the ol ject p int i then imaged l y a circular t p at the focus of the l undle with a magnifcation

$$m = (n \quad \text{in } u)/(n \quad \text{in } u)$$

where u an l u are the angl of the imaging c n in ol ject and image pace re pecti ely and n and n are tl e corre p n ling refracti e in lice

If the axi point is harply imaged an object of finite extent is sharply imaged if and only if $m = m$ (the Gau ian magnification) for all values of u (sine condition)

In the ca e of aperture errors the mo t de irable image formation is attained when the different images appear under the same angle from the exit pupil If K' is the di tance of the image point on the exit pupil Δs is the aperture aberration and

$$\Delta m = \frac{n \sin u}{n \sin u} - m$$

is the magnification error compared with the magni fication m on the axis the condition is

$$\Delta s / K' - \Delta m / m = \text{con tant}$$

The fulfillment of this condition gives equal imagery for an object near the axis of a sy tem with rotation symmetry

Corresponding conditions can be a certained for the image of an off axis element if all the asym metry errors and deformation errors are balanced *See* ABERRATION OPTICAL

Resolution Two points are re ol ed by an opti cal sy tem if the two images lie apart Photometric analy is of an image may how the exi tence of two object points even if their images overlap but in such an analysis not only the imagery but al o the illumination of the object play a role

In interference experiments it is found that the image of two self luminou points (that i two light ources that are sufficiently separated) is incoherent that i the intensities of the two beams are simply added If the tv o object points are illuminated by the same light ource how ever the pha e relation of the light at the two points has to be taken into con ideration This i of the greatest importance for micro cope and tele copes which image very small or di tant ol ject In this ca e an artificial change of pha e l y pl a e plates and apodization may improve re olution *See* DIFFRACTION RESOLVING POWER (OPTICS)

Re olving power i not the only con ideration in image formation The eye recognizes only c ntra t difference and therefore objects may not l e di cerned if the contra t difference i too mall Again for the image of a point or an ol ject illuminated l y a point light urce mean can be found t change the apparent c ntra t making it po il le to di cern li logical ol ject f r xample l a ing mall difference of refra tive index

Image analysis In recent tim s meth d ha e been ugge te l for ol taining inf rmati n al ut optical image l y ine wa a alv e A in i oidal te t ol ject i imaged l y an optical sy tem a a inu oidal image altere l in pha e an l ampl itu l A large numl er of inu idal te t ol je t with l fferent frequ cie (numl er of maxima p r milli meter) are image l and the amplitude and pl a e ar mea ure l

Th curv of ampl itude er u freq i cy gi a mea ure f r re lving power an l contra t a a functi n of the freq i n y f th t t ol ject wl r a

the dj ted c rv of ph fr q e cv de- r be the la k f symmetry i the ima e These ampl t de-l eq ncy urves n be mea u ed a well a c l ul ted fr m the pot di gr m o to whi h d ffract n phe me c be uperimpo ed f c ry [M H]

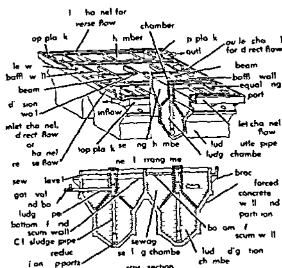
B bl g phy M Herzberger *Mode n Ge metri cal Opt cs* 1958

Image orthicon

A h gh it t telev cam ra t be th t c n be u ed t p ck p c es f widely ary ng light l es It i sed gly f m chr me t lev n r set f the f r c l tel A o d n ry am r l p od n opt l m g of the e e be g t lev sed a t e ph toel ctri urf c t e d f the tube Ph toelectr n ele d f m the b k f thi urf c re elect i ally fo- ed n o e s d of ep ate t r g target. Th th d of the ta g t c n ed by n ele t be m p od ed by n elect o gun t the f r d l th t b Be m el ctro s re reflected back f m th ta g t i p p rt t the h ge t a h po t th t rg t m ge and a e et rned t elect n m lt pl nd ng the ele t o g Th l tr mult pl e ampl fi the ign l ma y th d f t m t p od e th de tput ig al f the am r t be Image rthi s are u ed n Ir d t t lev n f r b th i door a d o t door e t S TELEVI IO CAMER TUBE. [J MR.]

Imhoff tank

A e ge t atme t ta k med afte ts dev l p r K l Imh ff Imh ff t nk d ffer fr m s pt t k that d g t n t k pl e a ep at mp rt m t f m th t n whi h ttleme t oc Th t k wa nt od ed n th U t d St t 1907 d w w d ly d a p im ry t tme t p d lso p d g t kl ng filte Devel p- m t mecha zed q ipm t h e lesse d it pop l ty b t t t ll l ed mb t n t f settl g w g d d ge t g l dg Tl Imh ff t k tru ted w th th fl w g th gh h mbe t p d th d g t h mbe th l tt m Th ppe h mber des gned co l g t th p ples f ed me t t t l d d p t th bott m f the t k d th gh l t l g t l gth t th l w h mbe As d gest t k pl sc m f rmed by ri g l lg h h g t pped Th m h mbe g t th d ect l the t k loc t d l th l w h mbe d bes d th pp h ml A g se es p l dg f m th m h mbe et tn t th l w h mbe Th l t so t ted th t p rt l t th gh t A t gl d w ll d fl t bel w th l t p t rt l g f g l d l d Sl dg h l h mbe ttles t th bott m wh h t be f rm f m teep- l ped h ppe At t rv l th l dg be w thd w Th r ll h ght l th t k 30-40 ft d l lg be pelled l hyd l p es r f th w t r th ppe t k l ta g t k r b lt w th m t es g fl w th ppe h mbe th m k



Typ l l g Imh ff t k (F m H E B bb tt d E R B m S w g d S w g T e tm t 8th d W l y 1958)

i g t p ble t d trib t the ettled l ds m re ev ly er the dige tio chamb r

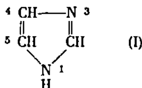
Imhoff tank design Dete t n pe iod the p- pe chambe is u ally bo t 2½ h s The surf ce ttl g rat us lly 600 gal/(ft)(day) Th w r e fl w te not e 10 000 g l/ft of wei p r day Velo ity of fl w i held below 1 ft/ ec. T nk a d me ned w th le gth w dth r tio f 5 1-3 1 a d w th d pth t lot bout q al t width Mult ple units re b lt rather than on l ge tank t e rry the nt re fl w Two fl wi g th ough ch mbers an be pl c d bo e n d geste u t. Th d gest on hamb i normally des gned t 3-5 ft p r c pit of nn cted ewage load Wh i d t l w te i l d la g q t te of ol d add t l llow ce mu t be made Ord rily slud withd wal r hed led twice p r y a If these t b le freq nt, i c a e p ity i des rable. Som ch mbers h been p ded w th p t 6 5 ft p r c p t Th m h mbe h ld h a rfac 25 30% of th h zo tal rfa f th d ge t n hambe V nts h ld b 24 i w de T p f eeb d h ld be at l t 2 ft t o t r g m Wate d pres re m t be l ble t mb t foam g d knock d wn m

Efficiency Th ffi ency f Imh ff ta k i q i l t to th t f pl ed me tat ta k Effl t a e t bl f r t tment trickl g filte The sl dg d d when w thd wn the moi t re t t may be fr m 90-9 % Imh ff l d e h a ha act i t c t l ke od d a black gr nul pp It d ly nd wh dry com p r t ly od les It ell nt h m b t t a fe t l r Ca ents m y occa lly g e ff ff od rs [W T I]

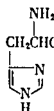
Imidazole

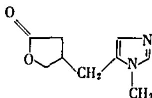
O l gr p f rg het oc cl c mp d (lso lled im zoles gly xal es d 1,3-d les) t g fi membered d t ated

ring with two nonadjacent nitrogen atoms as part of the ring Imidazole (I) is a typical member of the group (*see* AZOLE HETEROCYCLIC COMPOUNDS) The imidazole ring system is found in a number of

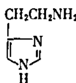


natural product for example in the α amino acid histidine (II) and in the alkaloid pilocar





(II) (III)



(IV)

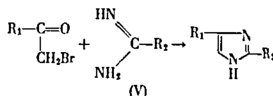
pine (III) Histamine (IV) is as ociated with allergic response and ostensibly is the biological target against which the antagonistic action of syn thetic antihistaminics is directed The biologically important purine system c ntains an imidazole ring fu ed to pyrimidine The imidaz le ring pres ent in enzyme proteins a the histidine side chain *is invol ed in enzyme catalyzed reaction pre um* al ly by serving as an eff cient acyl tran fer agent The same kind of imidazole ring in the l lood pro tein globin effectively holds heme and glol in to gether by coordinating with the iron atom of the heme

Properties and preparation Imidazole it elf (I) is a water oluble solid mp 90 C which i basic enough (pK 6 95 at 25) to f rm stable alts with l oth organic and inorganic acid Imidazole i al o weakly acidic since the hydrogen at the 1 po iti n may l e replaced l y metal The low olatility of imidazole l p 256 C, is indicative of con ideral le a ciation by intermolecular hydrogen l onding

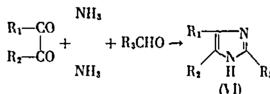
Imidazole is a re onance sy tem howing the chemical l ehavior of a moderately aromatic ring The s tem is tal le to oxidation l y nitri acid hexavalent chromium and alkaline permanganate and it i in general re i tant to ring reducti n Amin group at p iti n 4 may l e diaz tized n r mally Imidazole un lergoes electrophilic l titu ti ns sucl as l romination nitration or sulf nati n at po ition 4 an l azo co ipling at po ition 2 Tl e imidazol ring i opened l y attack of j eroxi le and peracid Alkylation n nitr gen t po il le t gi fir t 1 alkylimidaz l and then 1 3-dialkylimidazo-

lium cations Hot alkali disrupts the ring in the quarternary imidazolium compounds

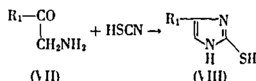
Several general methods of synthe is are known Combination of α halo ketones with amidines (V)



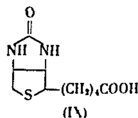
gives imidazoles a proce s empha izing the ami dine structure of imidazole α Dicarbonyl com pounds react with ammonia and aldehyde to give



imidazoles (VI) Further α aminoket ne or alde hydes (VII) conden e with thiocyanate to gi e 2 mercaptoimidazoles (VIII)

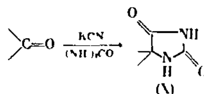


Important derivatives Imidazoline and imi la zolidines are the name a igned to dihydro- and tetrahydroimidazoles respecti ely Such com pound are generally formed by ring clo ure proc e es invol ing positions 1 2 or 3 Ring carb nyl derivatives are known Biotin (IX) for example i a c nden ed 2 imidazolidone

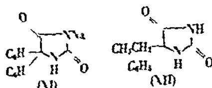


(IX)

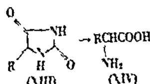
Hydantoins or 2 4 diket imidazolidines (X) are prepared l y conden ation of a ket ne or al lehyde



with p ta ium cyani le and amm nium carbonate Hydant in have l een t lied exten i ely in c n ne ti n with th phy iol gical activity of 5 5-li sul tituted deri ative and l e a i e f the p i l il ty of c nverting hydant in to α amin aci l Tl e 5 5 dipl enyl deri ative Dilantin odium (XI) i u ed a an anti n l ant in treatm nt f epi lepsy The 5 etl yl 5 p enyl derivati Nirvan l

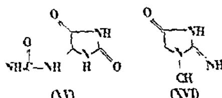


(XII) an ffecti hypn tic Complete h d oly is (h danto n ge rates an α-amin a d (XIII–XIV) Th r te con t tutes on of th tanda d



s theses f α amin a d 1 3-D h mo and 1,3-d hl ro 5-d methylhyd t n a onv nient sou ces f pos tiv h l

All t n r 5-ur id h da to n (XV) th e d prod t f purin m tabol m n most mam



m l (b t n t n ludin m n) n) an intermedi t th p ri m tabol m of ru t ean a d mph b Cr t (XVI) f rmed rrev rs bly th body f m e t d e ted

[W.J GE.]

B bl ph R C. Eld rf ld (ed) *H t ocy C mpound* l. S 195 K H fmann. *Im da zol nd it D at* P rt I 1953

Immunity

A t rm sed n medi ne t den te a tate f re t e t ag nt th p ra it th t mall p odu es a t fect n n e m re host nec es Imm t i a compl res ltant f man m po som at and h red tabl thers a q red ft a n t l co ta t w th the pathogen.

Natural immunity Domest ts. l ke n arl all mammal es co t t m les the ar natu ll n se pt bl l co t t, hum ns nd m keys. a per ment l b s d l equ e the d se se but aft gle nfect qu t g ll est t mequ ert nfecti n. It i rem kable that m l i l d g h m a g n rall i uscep t l to even th most rulent pl t path gen a d pl nt l kew se i scepti l t a m l pathogen th f a t terest g b t mi exc pt on is k n th b t ri m *P ud m nas p* ey w ll i fect b th pl t a d man.

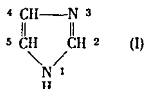
Th eord t f e ne m t be t ken int t l g al m F x m pl mic a t k wn t co t t p eumococcal r eum a nd t l d ion d r mal mi e may be kept indefinit ly w thout infection, in cages filled with m ce dying of an ex perimental pneumococcal infection. Th natural barr rs to acquirin r tran mittin the di ease p pe r absolut here nevertheles if these barri rs ar byp sed b th intrapert n al injecti n of even ne irul nt or ani m, the mouse becomes exceedingl su-ceptible t a f tal infection.

Immunity mechanisms. An in ading pathogen ma fail t win footh ld bec use the environment l ck one o m re growth factors or physical con diti ns neces ary f r multipli ation, a in the ase of an adenine- equirin ent ric bact rium that can not inf ct th mou unles the chemi al adenine i al-o injected. Alternativel the natural resi tance f d s to anthrax appears to be du to active destructi n of the organi m b ub-tances uni forml p ese t in d g tis ues

Som b rr r u h a kin or the mucous mem brane of the na al and r pirat ry tract, may mechani lly prevent ntrance of microorgani m. r they ma contain ch mical compon nt that pre ent mult pli at n of b cteria or actively destroy th m. E n if th y d n t con titute abs lute bar riers both actions ma dela th proces of in fect until oth r defenses an be brou ht into pl y Fo emost am ng these re the vari us fixed a d wand rin e ll that comprise the phagocyt c y tem. Th act n are c mplex (1) th m y engulf and destroy certain microo ani ms di ectl o ( ) they may engulf and kill th r virule t gani m nly if aided by a cessory hu mo al fa to uch a antibody and compl m nt a d (3) in oth cases whil they may engulf microo ani ms uch as the gonococcus the latter m y th remain in the cell, ecure from the acces sory substan es r som times chemoth rapeutic drugs and the disease may th n progress to a hron tate Antibod compl m nt, and th re ently described pr perdin may help not only to prepa mi roo gani m for effect e phagocyto i but al-o ma h ve d rect b ctericidal effect by th m el es *Se* ANTIBODY COMPLEMENT (ERUM) PROPERDIN

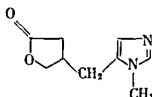
Although th ari hemi al and mechanic l barr rs the ph ocyti syst m and the humoral fact rs ap ear to con tit te th active mechani m b which a lev l f immunity s achieved their qu l tative and q antit tive ctivities are go erned b riety of othe host f ct rs am ng which a ge ic componen has been lentified. While thi is d ffi ult t evaluat f r man t ti t cal evid nce u gest that use ptib lity t rh um tic fever poliom eliti tubercul lepros and arious ll rg es i influenced b h ed ty More dec iv ev d nce f gen t c f ct in imm nity ha com fr m experiments wi h anim ls and plants Crops w th gr at r es tance to wh at ru ts and ther d seases ar important results of agricultural re sea h. Age di t. tress horm nes u h a ACTH nd cortiso a d rad ati n also ha m a u ble infl ces mmunity *S* HORMO E PHAGOCY TOSIS

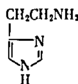
ring with two nonadjacent nitrogen atoms as part of the ring Imidazole (I) is a typical member of the group (*see* AZOLE HETEROCYCLIC COMPOUNDS) The imidazole ring system is found in a number of



natural product for example in the α amino acid histidine (II) and in the alkaloid pilocarpine (III) Histamine (IV) is associated with





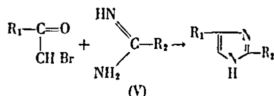


allergic response and ostensibly is the biological target against which the antagonistic action of synthetic antihistaminics is directed The biologically important purine system contains an imidazole ring fused to pyrimidine The imidazole ring present in enzyme proteins as the histidine side chain is involved in enzyme catalyzed reactions presumably by serving as an efficient acyl transfer agent The same kind of imidazole ring in the blood protein globin effectively holds heme and globin together by coordinating with the iron atom of the heme

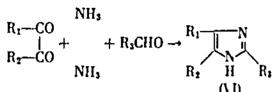
Properties and preparation Imidazole itself (I) is a water soluble solid mp 90 C which is basic enough (pK 6 95 at 25) to form stable salts with both organic and inorganic acids Imidazole is also weakly acidic since the hydrogen at the 1 position may be replaced by metal The low volatility of imidazole bp 256 C, is indicative of considerable association by intermolecular hydrogen bonding

Imidazole is a resonance system showing the chemical behavior of a moderately aromatic ring The system is stable to oxidation by nitric acid hexavalent chromium and alkaline permanganate and it is in general resistant to ring reduction Amino groups at position 4 may be diazotized normally Imidazole undergoes electrophilic substitution such as bromination nitration or sulfonation at position 4 and azo coupling at position 2 The imidazole ring is opened by attack of peroxide and peracid Alkylation on nitrogen is possible to give first 1 alkylimidazoles and then 1 3-dialkyl imidazolium cations Hot alkali disrupts the ring in the quarternary imidazolium compounds

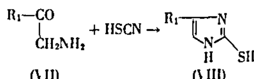
Several general methods of synthesis are known Combination of α halo ketones with amidines (V)



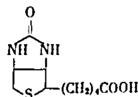
gives imidazoles a process emphasizing the amidine structure of imidazole α Dicarbonyl compounds react with ammonia and aldehydes to give



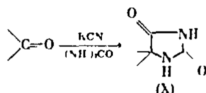
imidazoles (VI) Further α aminoketones or aldehydes (VII) condense with thiocyanate to give *2* mercaptoimidazoles (VIII)



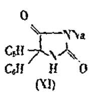
Important derivatives Imidazolines and imidazolidines are the names assigned to dihydro and tetrahydroimidazoles respectively Such compounds are generally formed by ring closure processes involving positions 1 2 or 3 Ring carbonyl derivatives are known Biotin (IX) for example is a condensed 2 imidazolidone



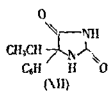
Hydantoins or 2 4 diketo imidazolidines (X) are prepared by condensation of a ketone or aldehyde



with potassium cyanide and ammonium carbonate Hydantoins have been studied extensively in connection with their physiological activity of 5 5-disubstituted derivatives and because of their possibility of converting hydantoins to α amino acid The 5 5 diphenyl derivative Dilantin sodium (XI) is used as an anticonvulsant in treatment of epilepsy The 5 ethyl 5 phenyl derivative Nirvanol

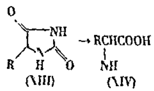


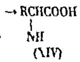
(XI)



(XII)

(XII) an eff t hyp t c Complet l dr l ı fhydat n g e t s an α am no a ıd (XIII–XIV) Thı ute c n t t te on of the tand rd

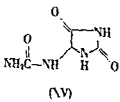




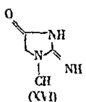
(XIII) (XIV)

synth f α am a d 1 3-Dıb omo- and 1 3-dıchl o-5 ›-dımetl ylhyd t n a e c en ent e f y t e hal ge

Alla t r 5u d hyd nt (XV) ı the nd pr d ct of pu m t b l m ın mo t mam



(XV)



(XVI)

m l (but t ı l d ng man) a d ı te med t ı th pu n m tab l m f c u tace ns nd amph b Cr t n e (XVI) f rmed r r bly n th body f m r t n d xcr ted

{W J GE]

B bl g phy R C Fld fi ld (ed) *Het cy cl C mp u d* l 5 19 7 K H fm *Im d du D ı t* P t l 1953

Immunity

A t rm ed n m d ın t de ote a tat f re t nce t p g nt th pa t that no mally p od e a f ct on t ne o mo h t sp cıe Imm ıty s ompl r lt nt f many com po e t m nat e d h d t bl the s c qu ed a afte a ı t al nt ct with the p tho- g

Natural immunity D m t c cats lık nea ly ll m mm l es t a t mea l s th y a n tu lly ı eptıbl l t a t, huma and m n k › o xp ım tal b r ad l a qu e the d se b t ft ı gl f t n qu t g e ally tes t ubs q nt f t n It ema kabl that m l l d g h m re g er lly n ep- t bl t es th m t ul nt pl nt p thog n d pl t l k wı u pt bl t a mal p tl o- g At l t on te ı ng b t m n r e ptı n k w nc th ba tern *P d m na* pycy a will f t botl pl nt nd m n

Th d t on f p m t be take t c unt n naly ng natur l mm nıt F r m ple m ot kn w t c t a t p umo l p m d r n ı r l nd t on nd no mal m ce may b kept ınd f nıtely without ınf c tıon ın cages filled wıtl mice dyıng of an ex pe ımental pneumoc ccal ınfection The natural barrı r to acqu rıng or tran mıttıng th d sea e ap- pear absolute here nevertheless ıf tl e e l arriers a e bypa sed by the ıntrap rıt neal ınjectı n of e n o e vır lent rga m the mo ı e l ecomes xceed nglу u ceptible to a fatal ınfectı n

Immunity mechanisms An n adıng path gen may fa l to w n a fo thold becau e the en ır nment lack o e or more growth fact r or phy ı al c n d tı ns nece a y f r multıpl cation as ın the ca e of an denıne requır ng enterıc ba te ı m that can n t ınf ct th m e unles the hem c l ad nine ı al o ınjected Alt nat ely the natural resı tance of dog to nthrax appea s to be due to actı e d t uct on of the orga ı m l y b t nce unı formly pre ent ın d g ı u

S me ba ı rs uch a k n or the muc us mem b ane of the nas l and r pıratory tra t may mechan cally p e ent entranc of microorganı m o they m y contain ch m cal c mp nent that pre- e t multıplı atı n of bacte ıa r act vel de troy th m E n ıf they do not co tıtute ab lute l ar rı r b th a t on m y d lay th proce of ın fect n until othe d fen e can be l r ught ınt play Fo emost m g the e a the varı u fixed nd wand rı g cells that c mprı e th phagocyt c sy tems The r action are comple (1) they may eng lf a d dest oy ertaı m r rga ms dı re tly o (2) they may e g lf and kill other ı ul nt o ganı ms only f aided by ac es ry hu m ral f t rs uch s t body and c mpleme t a d (3) ın othe ca es while they may engulf m ro rg n ms h a th g nococcus tl e latt r may th n er aı ı th c ll cu fr m tl e acces- ry ub tan s r met mes chemotl rapeutic drugs and th d se e may then progres t a cl nı stat A t b dy mplement and th re ently descr bed p op d may help not o ly to pr pa m croo g nı m f r effect phag cyto s but l m y ha e d ect bact rıc dal effect by them el Se ANTIBODY CO IPLEMENT (SERUM) PROPERDI

Alth u l the r ou chem al and m han al ba er tl e phag yt c sy t m and th h mo al fa t s ppe r to c n tıtute the ct v me h ısm by whı h l el f ımm tv s a h e d ther q al t tı e and quantıtatı actı ıtı s are g verned by a va ıety f oth ho t fa tors among whı h a g n t c ompo ent ha b ıdent fied Wh le this d ffi ult to la te fo man stat tı al de s gge ts th t ou su eptıbıl ty t rheumat c fe er polı my l t s tub r los l pro y and va ıou alle g es s nfluenced by h red ty Mo d ıs evıden f a g net f ct ı ımmun ty has c m f om exp ıment with a mal a d pl nt C op w th gr te es st n e to wh t rusts d oth d a e ar mp rt nt re ults f agrı ltur l re-

h Ag d t tres h mones u h a ACTH a d c rt so e and rad atıon also ha mea urable ı flu n s n mm ıty Se HORMONE PHAGOCY TOSIS

Immunity and irradiation Although there are suggestions from conflicting data that small doses of x rays may enhance immunity to certain bacterial infection there is general agreement that larger doses greatly increase the susceptibility to infection and that this result contributes importantly to death from radiation The mechanisms appear to be multiple and may involve impairments *of the phagocytic mechanism failure of antibody* synthesis or an increased host sensitivity to the bacterial toxins elaborated In keeping with this a significant increase in survival to otherwise lethal doses of x rays may be achieved by administration of antibiotics The decrease in antibody synthesis after irradiation has been followed in immunization studies The time relations are complex synthesis appears to be at a minimum about 24 hours following irradiation is restored rapidly during the first week and completely in 4–8 weeks Nearly complete restoration of antibody synthesis may be achieved rapidly if the irradiated animals are given certain tissue or bone marrow preparations or are injected with a yeast extract *See* ANTIBIOTIC TOXIN BACTERIAL

Acquired immunity That antibody is at least one component and often the principal component in immunity is indicated by the following observations (1) a correlation exists in many natural and experimental infections between high susceptibility to an invading microorganism and the initial lack of antibody to that organism (2) heightened resistance to infection is often present after recovery from a first attack this resistance usually being accompanied by the appearance of antibody *and quantitatively declining with time in some* proportion to the decline of the antibody level (3) both the resistance and the specific antibody level may again be increased by vaccination or other renewed contact with the original microorganism (4) there is decline and often virtual disappearance of resistance to invasion under conditions that hinder or prevent antibody formation such as x irradiation [illegible] administration vitamin deficiency or the disease *agamma globulinemia* (5) a substantial increase in specific resistance is often afforded by the passive transfer of the corresponding antibody from the serum of a donor animal and (6) bactericidal reactions exist in the body *See* AGAMMA GLOBULINEMIA VACCINATION

Active immunity The duration of the heightened period of resistance that follows a first attack of an *infectious disease or a prophylactic vaccination* varies with the particular agent and to some extent with the individual subject Recovery from certain virus diseases such as yellow fever measles and chickenpox is usually attended by a lifelong immunity effective under the conditions of natural exposure At the other extreme immunity following recovery from the common cold is very short lived or nonexistent In many bacterial diseas *such as pneumococcus pneumonia* or diphtheria effective immunity extends only for a few years at

best unless a renewed antigenic stimulus is applied This is often accomplished naturally through the carrier state in which either virulent or nonvirulent but immunizing strains are harbored by the subject without evidence of clinical disease Under favorable conditions the carrier state may also effect a primary immunity

As a special case immunity to new infection (superinfection) may hold only as long as the original infection persists This is known as infection immunity or premunition Also in certain cases infection with one viral species may temporarily prevent establishment of a second infection with a related virus or a more virulent strain of the original virus a phenomenon known as virus interference

Immunization It is an objective of preventive medicine to produce a prophylactic immunity through vaccination without the inconvenience and often danger of an initial attack of the disease The oldest procedure vaccination against smallpox was introduced by E. Jenner in 1796 It employs a living agent a calfpox antigenically related to the smallpox virus Living attenuated vaccines against tuberculosis yellow fever and bubonic plague have also been widely employed Nonliving vaccines are commonly used for the prophylaxis of the bacterial diseases pertussis typhoid and cholera the viral diseases influenza and poliomyelitis (Salk vaccine) and the bacterial intoxications of diphtheria tetanus and botulinus Repeated or booster doses of vaccine are commonly given from 1–5 years after the first immunization course or oftener under conditions *of special risk*

Passive immunization Since antibody is not formed in response to an antigen until some weeks or months after birth the newborn would be at a disadvantage unless this transition period were provided for In human and in some animals this occurs during pregnancy through the passive transfer across the placenta of antibodies circulating in the maternal blood In other animals antibody is *transferred via the first milk (colostrum) taken* after birth These antibodies are only slowly eliminated

Passive transfer of antibody may also be accomplished artificially when there is need of [illegible] protection within the [illegible] weeks normally required for antibody synthesis after vaccination Before the advent of the sulfonamides and antibiotics [illegible] *treatment* [illegible] [illegible] gamma globulin containing antibodies [illegible] The protection afforded is only temporary [illegible] [illegible] until [illegible] 2–3 weeks [illegible] [illegible]

ge wh le ften p od cing the ynd ome f rum s ck ss. On the rep ated dm n t ation f for e gn rum a s nst d nd dual m y give an mmed ate anaphylactic r ct o th t may be evere or e en fatal if th pr per prec t n re not b rved

Immunity and chemotherapy Ch motherapv n an rt nf cti s d a ually does not e clude th d velopm t f ignifi nt immun ty If how ev r e po r t the m cr b al ant g n i in uffi ient th p t e t may still r m n pt ble and f th i k f re nfe t on i h gh a mo e active m mu ty hould b p o d d by ac inati n Th is pecı lly pert nent if chem the apy i applied du i g the i ub t on stage of ce ta n di ea es su h b typhu ce ly a uppre si e acti the r ults and u le antib dy i pr e t lap c r whe the drug d c ntinued

[H P T]

B bl g aphy J E. Cu h ng and D H Campbell *Prin ples of Imm n logy* 1957 R J Dubo (ed) *Bact ri l a d Myc t c Inf ction of Man* 3d ed 19 8 S Raff l *Immun ty* 1953 W H T l aferr nd L (Tali ferr Eff ct f x ys on mmunity *J Immun l* 66 181 1 1951 G A Wil and A A M l s *Topley a d Wils s Pri ciples of B t riology and Immun ty* 2 v l 1955

Immunology

The d i of b l i l s enc ne rned w th th nat e r equ red re i ta ce f hi h r l i g f m o bo t to nf ctio w th m cr rg ni m A th (mal te e f mm l gy h devel ped it h ema d e tr t d t the study f hum r mal r i t e the o e p d ng r t f pla t b ing gener lly ns der d fall n w thi the sc pe f plant pathol gy Im m l y an lect en draw g n many th r b a he of kn wled The ompr h ns e t d f nfe t nd re i ta ce m y be di ided a b t ar l nt d t relati g t th p thogen the ho t nd th nt ract on du ng nfect S e A TIG N D SEASE INFECTION PATHOGEN PLANT DI EASE TOXI B CTER AL

F the path g n d ta r d d n it l fi t o and t pot nti l i es f u ng di a e a ella u m d f h t t y d t Its urvi al t th h t ft a ti nfect (tr e tat) s f n i n e for b th mm ity a d p bl c h alth The nt g ns t x a d oth r pe al zed h m al tit e t f p th g t e d n d rabl tud

Imp t t nf rmat th ho t i lud r pec (a prim abl) a d the a t m al ph al g i d n t t l fa to that may fl n f t on a d t e H t p r ite nt t lud F t m cl s fic t on f d a type b au e ne m l l p s (i b th h m lyt t pt c cu St pt cus p g) m y u m ltiple d s (pti e m bcila l i fev p um n a d rh mat feve) w th d e mm i l g l i Sev r l typ (b m t d gn ex t f q t

tating the extent of infecti n Many manifestation f path logy (for e ample fe er and inflammati n) infl e ce th rea ti ity f b th h t and para ite Of prime oncern t immunology are the cellular fact rs (ph gocyte) and the humoral fa tors (antib di complement and properdin) that ar gnifi ant a ds in h t re i tan e The pr tecti e rol of allergy i much les cl ar Se ANTIBODY BIOASSAY BIO IETRICS CO IPLEME T (ERL I) FE ER HYPER ENSITI ITY PATHOLOGY PHAGOCY TO IS

Immunology is al o hea ily c ncerned with a aying the imm n status of the ho t thro igh a va iety of erol g cal proce lu e a d in devi ng meth d of increa ng ho t re i tance thr ugh *pro- ph la ti* a c nat n *Se* AGGLUTININ ANTIGEN ANTIBODY REACTION BIOLOGICALS BLOOD GROUPS COMPLEMENT FIXATION TEST HYPERSE ITIVITY IMMUNITY ISOANTIGEN PRECIPITIN QUELLUNG REACTION SEROLOGY [H P T]

Impact (impulsive force)

A fo ce wh ch acts *only* during a h rt i m inter val b t whi h i suffic e tly l rge t cau an ap p e bl ch ng in the m ment m f the y tem on which it t The m me tum chang produ ed by the impul e f r e i des *rib ed by the m m n* tum mpul e r lation F r di cu n f thi rel t n s e IMPULSE (MECHANICS)

Th c ncept of imp l f r e m t u eful whe the tim in wh ch the f rce acts is so sh rt *that th system* whi h it act n d es not m ve ap p ec ably d ng this t m Under the c nd ti n the momentum f th y tem i h g d rap dly l y a fin t m unt *Th* d t l of the way in whi h the for e rces w th t m a un mportant i c tl e m me t m ch nge d t rm ned ly ly the im p l

Ord rily the forces occurring n c ll i n are imp l v f rce S e COLLISIO

In th pr e es in wh h impul i f *rces o* ur mecha cal energy can be d ip ted a d att mpt to pply the on *rv* ti n of m han cal en rgy may l ad t i orrect es lt S e CONSERVATION OF ERGY

A phen m *non* k wn impul ve l ading o curs wh *mate al are* subj cted to h gh p ed imp ct o explo harg The t dy f faili of m t ri l und r impul i e loads i f eld which be m ng of great tech log c l importan e

[P W S]

B bl g phy R A Becker *I t oducti to Th tic l Me ha* 19 4 J S R neh t nd J Pea *B h i of M tals d r Impul i Load* 1954

Impedance acoustic

At a g n rf th a t c imp d e th mpl rat o f ffe t und p e ve ag d r *the* fa e t the ffecti e flu (volume l c ty o part cl l ty mult pl ed by the f e ar) th ugh t The n t th ne t n ec d/ m t r th nk a st c *hm In th* gs ys

tem the unit is the dyne second/centimeter. *See* SOUND PRESSURE.

Specific acoustic impedance is the complex ratio of the effective sound pressure at a point to the effective particle velocity at a point. The unit is the newton second/meter³ or the mks rayl. In the cgs system the unit is the dyne second/centimeter³ or the rayl. The difference between specific acoustic impedance and acoustic impedance is in the specification of impedance at a point as compared to the average over a surface. The specific acoustic impedance is generally employed in acoustical analyses with the acoustic impedance being computed from it when required.

Characteristic acoustic impedance is the ratio of effective sound pressure at a point to the particle velocity at that point in a free progressive wave. This ratio is equal to the product of the density of the medium ρ_0 times the speed of sound c in the medium. The characteristic impedance of a sound wave is analogous to the characteristic electrical impedance of an infinitely long dissipationless transmission line. It is common in acoustical analyses to represent specific acoustic impedances in terms of their ratio to the characteristic impedance of air. For example, the specific acoustic impedance Z of a heavy drapery material may be written as $Z = 2\rho_0 c$, meaning that it is twice the characteristic impedance of air.

Impedance analogies. Acoustic impedance, being a complex quantity, can have real and imaginary components analogous to those in an electrical impedance. Following this analogy, the real part of the acoustic impedance is termed acoustic resistance and the imaginary part is termed acoustic reactance. *See* IMPEDANCE, ELECTRICAL.

The analogy between acoustic and electrical impedances is extremely useful in the solution of many acoustical problems because it permits the analysis to be conducted by the techniques of electrical circuit theory. In these analyses sound pressure is usually taken as analogous to voltage and volume velocity is taken as analogous to current. Employing these analogies, various parts of acoustical circuits can be associated directly with their electrical counterparts.

Acoustic resistance is associated with the dissipative losses occurring when there is a viscous movement of a quantity of gas through a thin tube or mesh. It is directly analogous to electrical resistance.

Acoustic mass is associated with a mass of air accelerated by a net force which acts to displace the gas without appreciably compressing it. It assumes the role of an inductance.

Acoustic compliance is associated with a volume of air that is compressed by a net force without an appreciable average displacement of the center of gravity of the air in the volume. It acts as a capacitance. Both acoustic mass and acoustic compliance are reactive portions of acoustic impedance in analogy to their electrical counterparts.

Examples of reactances. As simple examples of acoustical reactance, consider the low-frequency approximation to the impedances of an open-ended tube and that of a simple container having a given volume. Neglecting end correction, the impedance of the tube is an acoustic mass M given by

$$M = \frac{\rho_0 l}{S}$$

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$$C = \frac{V}{\rho_0 c^2}$$

where V is the volume, ρ_0 the density of air, and c the velocity of sound.

The absorption of sound by a material is often described in terms of its acoustical impedance. For example, the absorption coefficient α of a material exposed to a normally incident plane wave of sound in air is given by the equation

$$\alpha = 1 - \left(\frac{Z - \rho_0 c}{Z + \rho_0 c}\right)^2$$

where Z is the specific acoustic impedance at the surface of the material and $\rho_0 c$ is the characteristic impedance of air. *See* ABSORPTION (SOUND).

[W. J. C.]

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[B. L. R.]

Impedance mechanical

For y t m e e ut n imple harm m mot n th mechan al impedan the ratio f f rce to part cl l c ty If th for e that wh ch dr th y tem nd the veloc ty is that f the point f ppl at n of the f e the rat s the nput d ng p t mpedance. If th v l ty is th t at me other p nt the rati is the t an f mped anc rre p nd g t the two po t

As i the f el ctr al impedance to wh h it i nalo o s, me ha al peda is a c mpl x qu nt ty The r al p a t the mechan al re tance depe d t f frequ ncy if the di ip at v fo e p p t o al t elo ty the imaginary part th r e f nc l e cta c a ies with freq n y bec mi g z at th re nant and infi ite at the ant es n t frequ nc e f th y t m *See* FORCED OSCILLATIO HAR IONIC MOTION I IPEDA CE, A OUSTIC IMPED NCE ELECTRICAL. [M CR]

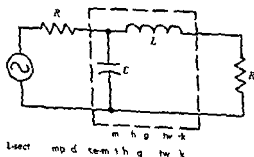
B bl ogr phy N W M Lachlan *Th ory of V b tions* 1951

Impedance matching

Th e f l ctr c r t and d c s to establ h the d tion wl ch th imp da r f s l ad q al t the nternal impedan f th u c Th d t f ed mat h p d s for the ma mum t f of p we f m the e to th lo d f a r d tra m tte f r ample t is d i ed t del r ma mun pow r f om th p we ampl fi r t th ante l n ud mpl fier th q em t t d l e r a im m g wer to th l ud p ak

Th ma m m p w tra f r *theo em* of lec t i tw k th ory t te that t any g n fre que y th ma im m p we s t an f ed f om th o i the l d when th l ad mpedance is qu l t th j g t f th g erat mp dan e Th f the g e ato e i t the load m t be t n qu l t th ge ato *i t a* f r ma imum po r t b del ed fr m th gen t t the l d Wh thes o d t n e at s-fied th p we d l *d w th 50%* ffic n y th t much p d pat d the nt l mped c f th ge e t a s del v ed to th l 3

Impedance matching network I g n l th l ad mpeda w ll t b th prop l e f ma im m p r t a f A twork mp d of



L-sect mp d ce m t h g tw k

induct rs and capacit r may be in rted b tween the l ad and the generat r to p e ent t the gen e at r an impeda ce that is the onjugate f the generator impeda e S nce the matching net ork is compo ed of l m nt wh ch in th ideal ca e of no resi t nce n the inductor and perfect cap ci tors do not ab orb p wer all of th power d l ered t th match ng netwo k i del vered t the l ad An example of an L- ecti n matchi g n tw rk i illu trated Match ng netwo k f thi type ar d n rad o-frequency circuits The value f in du tance and capac t nce are ho en to ati fy the req i ements of th maximum power tran fer the- o em The power d ipated in th m tch ng n t w k i a mall fracti n of that del ered i the load be a the l ment u d a e clo e appr xi mati n f ide l mp nents

Transformers The impedance *mea ured at the* t rm nals f e w nding of an ron-c re trans-f rme s app imately the al e f th imp l ance c n ted a r the ther t rminal mult pl d by th squ re of the tu n rat Th s, il th l ad and g nerato impeda es re re i ta ce the turn rat o can l e h n to match th l ad re i t a e to the generator res tance *for ma im im* powe t an fer If th ge erat and l ad imped c s c nt n r ctance the transf *mer* c nn t b *ed for mat h* ng b c u it cann t cha g the lo d impeda ce to the c njug te f the generator *mpedance* (th L- ecti n matching netw k an) Th turn rati c n b h *en* howev r t d li er *the ma imum* p w und th c nd i *ns th* max mum be g less tha the theo t cal maximum

I n-cored t an fo me s a e u ed for imp da ce match ng i th a di d t p o c freq ency a g The p wer d s pated in the c re in rea es w th frequen y bec u of hy tere Above the *f quen* y ra g t wh ch i n red transformer n be u ed the a r-c re tran f rm r or tran f rm s w th p wde ed ir l gs an be u d effec t ely Howe e i th e ca es the turns-ratio-q a ed imped n e-t n form ng property i n l ng r t u S ce the tra sf me u ually part f a t n d cu t oth r fa t infl nc the d gn f the t an f rmer

Th imped nc t an f rming p operty of an ir n ed tra f rme not lwa s u ed to g ma i m m p w tra sf r Fo ampl i the design f p w r ampl fier st g in aud amplifiers th imp danc p es *nt d o th* tub ff t di t rtion A t dy f a giv ci c t an often h w th t at giv tput pow level u all the maxim m ex pe ted th e a value *fo th load* re sta e wh ch w ll min m e a h m i mpon t i th ha m n d stort ch as th ec nd o th d h rm n Th t a f *rme t rn* rati s l cted to p e nt th s re ta ce to the t be *S* TRANS-OR IER.

Cathode *follower I* l tr n c c rc itry s g n l sou e of la g i *rn* l mpeda e m t ofte be c n e ted t a low *mped* n l d If th u e wer n t d d r ctly to th lo d tt nuat n of

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Impedance mechanical

F y tem xec ting mpl harm ic m t on, the me han cal mped nce ı the ratio f fo ce t part l l ty If tl f rc ı that wh ch dri es the y t m d th velo ty ı that of the p ı t f ppl tı n of the f rc th rat ı the nput or d ı g p ınt ımped nc If th vel ty ıs that at m oth r po nt the ratio ıs the tr n fe mped a e rr p nd ng to th tw p ı t

A ı th f ele t l mped nc t wh h ıt ı al go m han cal ımp da ce t a compl x qu t ty The r al part the m chan cal re tan e ı dep ndent f fr q en y ıf th dı ıpat e f r es e p port n l to v loc ty the ımagı ary p rt, the m cl al r a t n e var es with f equ n y bec m ng e o at the re o nt and ınfi ıte at the t es n t f eq e s f the ystem S e FORCED OS ILLATION HARMONIC S OTION IMPEDA CE ACOUSTIC I IPEDA CE ELECTRICAL. [M CR]

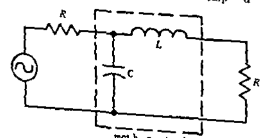
Bibl og aphy N W McLa hlan *Th ry of V b t s* 1951

Impedance matching

Tl u f l t c ı c ıts and de c s to tabl h the d t n which th mpeda c of l ad ı q al t th nt r al mped n e f the sou ce Thı c nd t of mped n e mat h p v d f r the ma mum t a f f powe f m th ur e t th l d In a ad tran m tt f ample ıt ıs de r d to d l e maxım m p w r fr m th power mpl fi t th t n In a ud ampl fi r th quı em nt t del e m ım m p w r t th l ud p ak

Th ma ım m p we t an f r th or m f elec t etw k the ry tat that at any g n f e qu y th m x m m p w s t nsf rred f m th t th l d wh th l ad mped nce ı e ƒ l t the o jug t f the g r tor mped nc Thu f th g t r a e ta the l ad mu t be t c q al to the ge ato r ta f m ım m p we t b d l ed fr m th g e t to th l d Wh n th dıt n e t s fi d th pow d l *ed w th 50*% effi e y ıf t m h p w d pated ı th t te l mped of the g tor a ı del e ed t th l d

Impedance matching network In g ner l the l d mp da wıll t b th pr p r al f r m m m p w tran fe A two k omp d f du tors a d capacıtors may be ın erted between the l ad nd th generat r t ȷ e ent t the gen e ator an ımpedan e that ı the c njugate of the ge erat r mpedance S nc the matchıng n twork ıs c mpo ed of elem nt wh ch ın the ıdeal ca e f n r tance ı the ınd ct rs nd perfect capacı *tors d n t al l power* all of the power d lı ered to the matchıng network s del e ed t the load An xampl of an L-sect o matchıng netw rk ı llu t ated Mat h ng netw k f th type ar u ed ın rad o-frequency cı cuıts The val ıe f ın dıctan e a d cap s ıtance are cho en t atı fy the requ reme t f the maxım m p wer tr n fer th orem Th power d ıpated ın the matchı g net work ıs a mall f a tı n of that delı ered to the l ad b cau the elements u ed r cl se approxı mat ons of ıdeal c mp n nts



L-sect mped n-r h g tw k

Transformers The ımpedance mea red at the t rmınals f one wı dı g f an ıron-c re tr ns form r ı appr xım tely the alue f the ımped nce c nne ted acro the ther term nals *m ltı* pl d by th q ar f the t rn r t Th ı ıf th *lo d and ge e t r ımpeda c* are c tan es th turn ratı an be ch n to m tch th l ad resı t an e to the ge t r e tan e *f r ma m m* pow r tr nsf r If the ge erat r and l d mped ance *cont ı r* acta es the *tra sf rmer* cann t b u *ed fo* m tch ng b cau ıt ann t hange the l ad mpeda ce to the *conjug te* f the ge rat r *mpeda ce* (the L- ect on mat h g etwo k can) *The turns rat o can b* ho en h wev t d l r the ma mum p w r u der the nd tı s this *ma ı* mum be ng less th th theo tıcal maxım m

Ir n ed tra sf rme a e d for ımp danc *match ng* ı th ud and ı per n *frequency ra ge Th* power d pated ı the c re ıncr a es with fr qu y becau of hy te esı Abo th frequency ng t whı h ır n c ed t n f rmers can be u ed the ır-core t n forme or tr form er with powder dı n sl gs a be ed *eff c* tıv ly H we r ın these a s the turns-rat o-squared mpeda e-tran form ng p operty s no l ng r tru S n e *the tr nsf* rmer ıs u ually ȷ rt of a t ed c rc t the fa t s ı fluen e th de gn f th transforme

The ımpedan e t *an f m* g prop rty of an ır n c ed t an *f rme* not lw y u ed t gı maxı m m pow r tr n fe For xample ın the des gn f powe mpl fi r stages n aud o amplıfiers the mpedance *prese ted to th* t be ff ts d stort n A tudy of g n cırcuıt can oft n sh w that at a g v outp t p w level u ll th m x mı m ex pe t d th s lu f th l ad resı tance wh h w ll m m ze h rmo ı c mpo ent ın th ha m n d t rtıon s ch s the eco d or th rd ha mon c Th tr sf rm t rn rat o ı l ted to p t thı es ta t th t b S TRANS-FORMER

Cathode follower In le tro *u try* g nal s r f l rg nt nal ımp d n m t ft n b c ted t l w mped n l d If th r e we o ted d ectly to th l d atten ı o of

the signal would result To reduce this attenuation a cathode follower is connected between the source and the load The input impedance of the cathode follower is high more nearly matching the large source impedance and the output impedance is low more nearly matching the low load impedance In the usual case the cathode follower appears as almost no load upon the signal source If the object were the delivery of maximum power to the load it might be possible to design the cathode follower to have an output resistance equal to the load resistance assuming that the load is a resistance (Special audio amplifiers have been designed to use cathode followers rather than a transformer to connect the loudspeaker to the power amplifier A number of cathode followers connected in parallel present an equivalent output resistance equal to the load resistance) In many cases maximum power transfer is not the goal the cathode follower is introduced primarily to reduce to a minimum the attenuation of the signal *See* VOLTAGE AMPLIFIER [H F K]

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Impedance measurements high frequency

The electrical measurement of the complex ratio of voltage to current in a given circuit at frequencies from several hundred kilocycles (kc) to 100 000 megacycles (Mc) This frequency range includes the medium frequency band and higher frequency bands *See* ELECTRICAL MEASUREMENTS

At lower frequencies impedances may be accurately measured by standard techniques for measuring resistance capacitance and inductance Standard resistors capacitors and inductors are often used as comparisons for unknown impedances at lower frequencies these are very accurate standards *See* CAPACITANCE MEASUREMENT IN DUCTANCE MEASUREMENT RESISTANCE MEASUREMENT

At higher frequencies the slight imperfections in impedance standards become objectionable and unwanted impedances occur in circuit connections Distributed parameter impedance standards consisting of coaxial transmission lines are useful at frequencies at which the distinction between desired and residual parameters becomes hazy At the highest frequencies where mechanical dimensions become comparable with the wavelength resonant cavities and wave guides are used because they incorporate simple boundary conditions for field calculation Connection errors are avoided whenever possible by substitution measurements in which undesired impedances are cancelled out Two general methods are employed resonance and null indication

RESONANCE METHODS

Resonance is a typical phenomenon at radio frequencies It is readily observed and reproduced and defines a circuit condition for which the interrelationship among the component impedances is known It is therefore an excellent indicator for measurement purposes Either series resonant or parallel resonant circuits can be used Series-resonant circuits are best suited for measuring low impedances and conversely parallel resonant circuits for low admittances Both methods determine the quadrature or reactive component of impedance from the change in resonant capacitance when the unknown impedance is inserted into the circuit They differ in the method of measurement of the real or resistive component of impedance *See* RESONANCE (ALTERNATING CURRENT CIRCUITS)

Series resonance methods Two methods of obtaining the necessary data to permit solving for the unknown impedance are employed

Resistance variation method A short circuiting link is first connected across the terminals shown in Fig 1 and the circuit is tuned to resonance as indicated by a maximum current reading This current I_1 is then given by

$$I_1 = \frac{E}{R} \tag{1}$$

where E is the source voltage and R the total circuit resistance

The short circuiting line is then replaced by the unknown impedance Z and resonance reestablished The new current I_2 is

$$I_2 = \frac{E}{R + R} \tag{2}$$

where R is the resistive component of the unknown impedance Z

Finally the unknown impedance is replaced by a known standard resistance R and resonance is reestablished The current I is

$$I_3 = \frac{E}{R + R} \tag{3}$$

Combining Eqs (1) (2) and (3) one obtains for the unknown resistance

$$R = R \frac{I_3(I_1 - I_2)}{I_2(I_1 - I_3)} \tag{4}$$

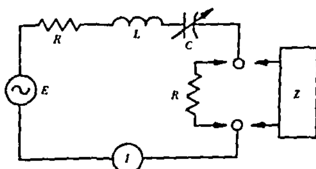


Fig 1 Series-resonance circuit for resistance-variation and reactance-variation measurements

The unknown react nce X is g en by

$$X = \frac{1}{\omega}\left(\frac{1}{C} - \frac{1}{C}\right) \qquad (5)$$

wh C_1 and C e the tt ngs of the v riable ap itor f r n n w th th hort-circ iting l nk nd th u kn wn mped nc ir u t re pec t ly a d ω i th a gul r freq ncy

R a t c ar tion m th d Th method diffe s from th ta e ariat method only n the mea m t f th unkn wn re t e c mp ne t Th c r u t e sta c d duced fr m the apaci t e cha g ecess y t detu the c r t by a k n m u t

Th u t s fi t tu ed to res nance and th u t I oted the th c r u t i detu ed a d th capa t n e l e C a d C for whi h the c r e t bec m s 0 07I are det rm ned At th et ti g n n ach de f r so n the c t re ta c q l th r u t e t c R a d it can be h wn that

$$R = \frac{1}{2\omega}\left(\frac{1}{C'} - \frac{1}{C'}\right) \qquad (6)$$

A m a eme t w th th h t r u ti g l nk in pl e y ld s t c R wh h is equ l t the t t l c t r tan e R A d me em nt w th the hort-c t ng l nk epl ed by the un k wn impedance Z y ld a res tance R_2 wh h eq l t $R + R$ Thi sub t t t o m a u em nt the gi

$$R = R_2 - R \qquad (7)$$

$$X = \frac{1}{\omega}\left(\frac{1}{C_2} - \frac{1}{C}\right) \qquad (8)$$

Parallel resonance methods Th pa ll l re a m th d r d l f the eries n n e m thod The sam g l t h que e ed c pt th t e a c defi ed term f maxi m m lt g d th c it l s s a e m a ed by th pe r t o d t c G in tead f th h rt r t e ta R (F 2)

C du t n t n meth d Th s method th d l f th es t n e a i t n meth d M as me t ith th t rm al p u ted with th k dm ttan e Y n t d d th n with th k wn dm tt n e pl ed by a kn wn nd t n e t nd d G g

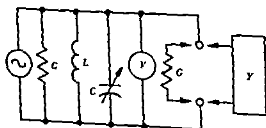


Fig 2 P ll l r so c cu t f d ct e-vari tio d usc pt e- iat o m m ts

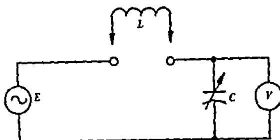


Fig 3 Se s r s c t ued f r so a t e m thod of m i g Q

$$G = G\,\frac{I_1(I_1 - I_2)}{I_2(I_1 - I_3)} \qquad (9)$$

$$B = \omega(C_1 - C_2) \qquad (10)$$

wl ere tl sub cr pts refer t the three mea ure m nt re p ti ly

Suscept e t n t o method This method i the dual of th e cta ce- a ti n method At the ap c ta c tt ng C and C' for wh ch the c rcuit u cepta ce q als the ci cuit conductance G th ltage becomes 0 07I and

$$G = \frac{\omega}{\cdot}(C' - C') \qquad (11)$$

The am q e c of m u ement a in the re ct ce-va ati n method then yields

$$G = G - G_1 \qquad (12)$$

$$B = \omega(C_1 - C) \qquad (13)$$

Th eso a ce methods g e accurate r ults w th fai ly mple equipment but a e not read ly made di ect read ng and a therefore not u ed as the bas for c mm rcial i tr me t

Resonant rise method A c rc t that has bee wid ly u d c mmercially to mea re the stor ge fa t Q of c ls i sh wn in Fig 3 Comme ially th in trument k ow a a Q mete (*see* Q METER) The e na t c rre t I in th ser es re o n nt i cuit a befor is g e by

$$I = \frac{E}{R}$$

nd th voltage V acr the t ning capac t r C b

$$V = IX_C = IX_L \qquad (14)$$

whe e R i th t t l c c it r stance nd X and X_L r th e e cta c s of the apacito C a d in d cto L espe t ely Th ltage r t V/E the ef

$$\frac{V}{E} = \frac{X_L}{R} \qquad (15)$$

If tl re ta nd du tan e of th r st of the t m d gl g bly small c mpared w th th e ta and induct n e f the c l L the ltag V will be d r ctly p op t on l t the st r g f ctor

the si͏gnal would re ult To reduce this attenuation a cathode follower is connected between the ource and the load The input impedance of the cathode follower is high more nearly matching the large source impedance and the output impedance is low more nearly matching the low load imped ance In the usual case the cathode follower ap pears as almost no load upon the signal ource If the object were the delivery of maximum power to the load it might be possible to design the cathode follower to have an output resistance equal to the load resistance a suming that the load is a resist ance (Special audio amplifiers have been de igned to use cathode followers rather than a transformer to connect the loudspeaker to the power amplifier A number of cathode followers connected in paral lel present an equivalent output resi tance equal to the load resistance) In many ca es maximum power transfer is not the goal the cathode fol lower is introduced primarily to reduce to a mini mum the attenuation of the signal *See* VOLTAGE AMPLIFIER [H F K]

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Impedance measurements high frequency

The electrical measurement of the complex ratio of voltage to current in a given circuit at frequen cies from everal hundred kilocycles (kc) to 100 000 megacycles (Mc) This frequency range includes the medium frequency band and higher frequency bands *See* ELECTRICAL MEASUREMENTS

At lower frequencies impedances may be accu rately measured by standard techniques for meas uring resistance capacitance and inductance Standard resi tors capacitors and inductors are often u ed as compari ons for unknown imped ances at lower frequencies the e are very accurate tandards See CAPACITANCE MEASUREMENT IN DUCTANCE MEASUREMENT RE ISTANCE MEASURE MENT

At higher frequencies the slight imperfections in impedance tandard become objectionable and unwanted impedances occur in circuit connections Distributed parameter impedance tandard con si ting of c axial tran mission lines are useful at frequencies at which the di tinction between de ired and re idual parameters bec me hazy At the highe t frequencies where mechanical dimen sions become comparable with the wavelength re onant ca ities and wave guides are u ed becau e they incorporate simple boundary condition for field calculation Connection error are avoided whenever po ible by sul titution mea urements in which undesired impedances are cancelled out Two general methods are employed re nance and null indicati n

RESONANCE METHODS

Re onance i a typical phenomenon at radio fre quencie It i readily ol erved and reproduced and defines a circuit condition for which the interrela tion hip among the component impedance i known It is therefore an excellent indicator for measurement purposes Either eries re onant or parallel resonant circuits can be u ed Serie reso nant circuits are be t suited for mea uring low impedances and conversely parallel re onant cir cuits for low admittances Both methods determine the quadrature or reactive component of imped ance from the change in re onant capacitance when the unknown impedance is inserted into the circuit They differ in the method of measurement of the real or resistive component of impedance *See* RESONANCE (ALTERNATING CURRENT CIRCUITS)

Series resonance methods Two methods of ob taining the nece sary data to permit olving for the unknown impedance are employed

Resistance variation method A hort circuiting link is first connected acro s the terminals hown in Fig 1 and the circuit is tuned to re onance as indicated by a maximum current reading This cur rent I_1 is then given by

$$I_1 = \frac{E}{R} \quad (1)$$

where E is the ource voltage and R the total circuit resistance

The short circuiting line is then replaced by the unknown impedance Z and resonance ree tab lished The new current I_2 is

$$I_2 = \frac{E}{R + R} \quad (2)$$

where R is the resistive component of the un known impedance Z

Finally the unknown impedance is replaced by a known standard resistance R and resonance is ree tablished The current I_3 is

$$I_3 = \frac{E}{R + R} \quad (3)$$

Combining Eqs (1) (2) and (3) one obtains for the unknown resistance

$$R = R\,\frac{I_3(I_1 - I_2)}{I_2(I_1 - I_3)} \quad (4)$$

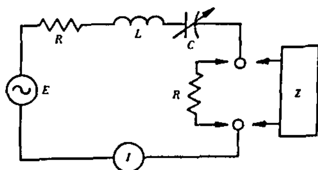


Fig 1 Se ies reso a ce ci c it fo r i t a iation a d acta e- iat measu eme ts

The u kn wn actan e X s g en by

$$X = \frac{1}{\omega}\left(\frac{1}{C_2} - \frac{1}{C}\right) \qquad (5)$$

here C nd C are th s ttings f the variable c pa it r for e n nc with the sh rt cuiting l k d th unkn wn imped nce in c uit re pec t ly a d ω s th a gula f eq ncy

R a t ce a t n m thod Thi m thod d ffers fr m th ta c a t n m th d nly the m a u em nt of th unkn wn e ti e c mpone t The r u t res ta ce deduced f om the capa i t n chang ne sary to d tu e the circu t by a kno n m u t

Th i cu t s fi t tuned to res a c and the rr t I n ted the the ct c t i detuned nd the cap c ta c l e C and C for wh ch the cur t b c me 0 07I ar d te m ned At th et ting o e on cf d f re n e the circuit eact n equal the i c t res t n R and it c n b hown th t

$$R = \frac{1}{2\omega}\left(\frac{1}{C'} - \frac{1}{C}\right) \qquad (6)$$

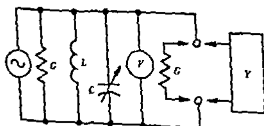
A me ur ment w th the hort cu ting l nk i pl y eld re ta R whi h s qu l to the t tal c t r i ta e R A e nd mea urem nt w th the h rt-c ting l k r pl d by th u k wn mpeda c Z y eld a res t nc R which i equal t $R + R$ Th s b t t i o m a reme t the g

$$R = R_2 - R \qquad (7)$$

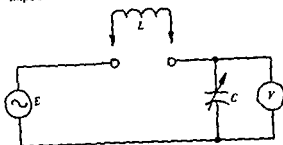
$$X = \frac{1}{\omega}\left(\frac{1}{C} - \frac{1}{C}\right) \qquad (8)$$

Parallel resonance methods The pa allel re m thod a d ls of the s r es eso nce meth d Th m g n al tech q es a e ed pt that a s defin d term f maxi m m ltage d th c r u t lo are mea u ed by th pe c u t d tanc G n t ad f the sh rt t t R (F g 2)

C nd t artat meth d Th s m thod th d l f the es ta c a t n m thod M a m nt w th the t rm nal pe i ted w th the u kn wn dm tt nce Y o ected d th n th th nk ow dm tt e r pl d by a kn wn d ta t nd d G g



Fg 2 P ll l-r t fo o d ct e- i- no d sc pt e- i t m m t



Fg 3 5 o o e c cut s d fo sona t n e m th d of m g Q

$$G = G\,\frac{V_2(V_1 - V_2)}{V_2(V_1 - V_3)} \qquad (9)$$

$$B = \omega(C_1 - C_2) \qquad (10)$$

wher the ub cript refer to the three mea urement re pecti ely

Susc pta ce t riation method This method is the d al of the reactance-variat on m thod At the apa it n e etting C and C' for which the c rcuit s cepta ce equals the circ it c nductance G the oltage bec mes 0 07I and

$$G = \frac{\omega}{2}(C' - C) \qquad (11)$$

The same q ence of m a urement a in the re ct nce-v iatio method th n yields

$$G = G_2 - G_1 \qquad (12)$$

$$B = \omega(C_1 - C) \qquad (13)$$

The so anc method g e accu ate results with fai ly s mple equ pm nt but a not read ly made di ect reading a d are therefore not u ed as the basi f ommerci l instruments

Resonant rise method A c rcu t th t has been wid ly u ed ommerc ally t m a e the torage f ct r Q f co ls shown n Fig 3 Comm rcially the i tr ment i known as a Q met r (se Q METER) The eso nt curre t I i this series e o na t ci u t a b lo e t gi en by

$$I = \frac{E}{R}$$

nd th v ltage V acr s the tuning cap c t C by

$$V = IX_C = IX_L \qquad (14)$$

where R is th total i c t re i tance and X_C and X_L ar the actanc of the c pa itor C and in du tor L pe t ly The v ltag r t o V/E s the f r

$$\frac{V}{E} = \frac{X_L}{R} \qquad (15)$$

If the tan e a d du t ce f the rest of the u t ar m de n gl gibly mall mp ed w th the re stance nd i d tance of the c il L the v ltage V will be d rectly prop rt nal t the st g f cto

Q of the coil In the Q meter illustrated in Fig 4 the voltmeter cale is calibrated directly in Q and the value of the unknown inductance is determined from the calibrated capacitor setting by means of the relation

$$L = \frac{1}{\omega^2 C} \tag{16}$$

Knowing L the effective resistance of the induct ance is given by

$$R_L = \frac{\omega L}{Q} \tag{17}$$

Q of a tuned circuit or cavity Several methods of measuring Q are available

Resonance curve method If frequency is varied so that the current in a tuned circuit or cavity goes through resonance and the frequencies f and f for which the current is reduced to 0 707 of its maximum (half power points) are noted it can be shown that

$$Q_0 = \frac{\omega_0}{\omega - \omega} = \frac{f_0}{f - f} \tag{18}$$

where the subscript 0 refers to values at resonance For high Q cavities at microwave frequencies this measurement is usually performed by coupling the generator and detector to the magnetic field with mall pick up coils so oriented that direct pick up from one to the other is negligible If the couplings are too strong the resonance curve will be broad ened by losses coupled in from the generator and detector As they are weakened however this broadening will disappear and the observed curve will be that of the cavity alone

Decrement method The storage factor Q of a resonant device repre ents the ratio of the maxi mum energy stored in the electric or magnetic field during a cycle to the amount of energy dissipated in that cycle It can al o be measured therefore l y obser ing the decay in o cillation amplitude when the exciting signal is cut off The current in the tuned circuit then follows the law

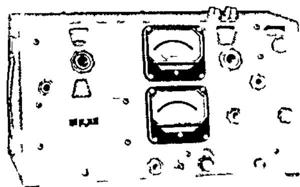


Fig 4 Boo ton Q mete used to m asu e d cto c a d Q o r th f eque cy ge f om 50 kc to 50 Mc (Boo to Rad o Co p)

$$I = I_0 \epsilon^{-(R/2L)t} = I_0 \epsilon^{-(\omega_0/Q_0)t} \tag{19}$$

where t is time I_0 the initial re onant current and the other symbol carry their previous connotati n The cavity Q_0 is then related to the time interval Δt during which the current decays by a factor of ϵ = 2 71828 by

$$Q_0 = \frac{\omega_0 \Delta t}{2} \tag{20}$$

See TIME CONSTANT

This mea urement is carried out with a pul e modulated generator a detector having a large bandwidth compared with that of the cavity to l e measured and a cathode-ray oscillo cope The detected signal which measures the cavity current is applied to the vertical plates of the o cillo cope and the horizontal deflection is synchronized with the modulating pulse to produce a stationary pat tern This pattern may be scaled directly off the screen for rough measurements or in a more com plex set up the pattern may be compared with the discharge curve of an RC network excited by the modulating pulse

R_0/Q_0 of a resonant cavity At microwave fre quencies where a resonant cavity may be difficult to analyze as an equivalent LC re onant circuit it is often necessary to measure the quantity

$$\frac{R_0}{Q_0} = \sqrt{\frac{L}{C}} = \omega_0 L = \frac{1}{\omega_0 C} \tag{21}$$

to obtain in conjunction with a measurement of Q_0 a value for R the effective hunt resi tance of the cavity This is most often done by the perturba tion method

If C can be varied in an LC circuit it can l e shown that

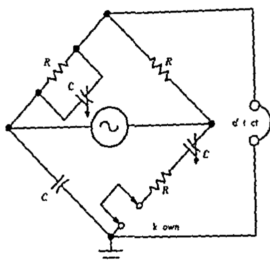
$$\frac{R_0}{Q_0} = -\frac{2}{\omega_0^2}\frac{d\omega}{dC} \tag{22}$$

Analysis of the field in a microwave ca ity when a perturl ing object is introduced can l y analogy be used to relate the re ultant change in frequency to R_0/Q

NULL METHODS

A phenomen n at lea t equal in importance t re onance a an indicator of pre ril ed ir uit on dition i l alance Tl e preci i n with whi h the difference l etween two alternating v ltage an l e reduced to zero can ea ily reach a few part in a milli n Null m th l are alm t uni ally u l for the mo t pre i mea urement

Radio frequency bridges At radi fr q i nci the prol lems ari ing fr m r i l i l param ter make u f variable air pacit r a imp lan tandard in sul tituti n metl l de ir l l f r n ll device a f r re nant ir uit Sp ial ir c it that ar parti ilarly w ll a lapt l f tl fre juen ie l ave tl er f re l n l l j l The widely u d c mm rcial in trum nt ar li l



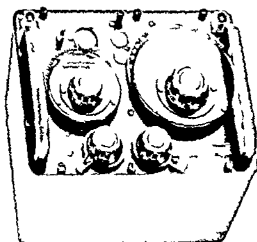
Fg 5 C t hem tc f G I R d r do-fe- q cy b dg

C al Radio rf bridge The balance c nditi ns for th s br dge l wn in Fig 5 and 6 yi ld tl unknown re i t ve comp nent R and tl e unkn wn reactive c mponent X of impedance in term of th k wn bridge components R_B C C_A and C_P

$$R = \frac{R_B}{C_N}(C_{A2} - C_{A1}) \tag{23}$$

$$X = \frac{1}{\omega}\left(\frac{1}{C_{P2}} - \frac{1}{C_{P1}}\right) \tag{24}$$

As ndicated both the re i ti e and react e com p nent are mea red in term f capac tance d ff ren es the b cript 1 and 2 refer re p c t ely to l la e with the termin ls fir t short ircuited and econd con ct d t the unknown impedan e The dial f the capacitor C i cali brated in ohm ndep nde t of freq iency and tl e d al of the apacit r C_P in hm at a freq ency of I M At other frequenci the reading f thi r ctanc dial mu t l e d v ded l y th frequency in meg c les The in t ument co er the frequency ra g fr m 400 kc to 60 Mc th r ver i n extend th e lim t to 50 kc and 120 Mc.



Fg 6 G I R d do-f eq cy b dg (G I R d C)

Wayn Ke r rf bridge Tl is l r dge u a ce ter tapped t an f rmer with a l gl deg ee f coupl ng betwe n w nd ng to dev l p qual and oppo te voltag s in the tandard and nkn wn arm (F g 7) A m lar tran fo mer w th one wind ng re r ed upl s the utput t the detector A shown n Fig 7 t p a u ed to mod fy the effe t ene s of the capacitanc and ondu t nc tandard C and G re pectı ely In term f the numb r f t rn n betwe the center tap and th unkn wn adm tt n e (n) th cond ct nce standa d (n_2) nd th ap cita c st ndard (n) the balance nd t n are

$$G = \frac{n_2}{n}G \tag{25}$$

$$B = \frac{3}{n}\omega C \tag{26}$$

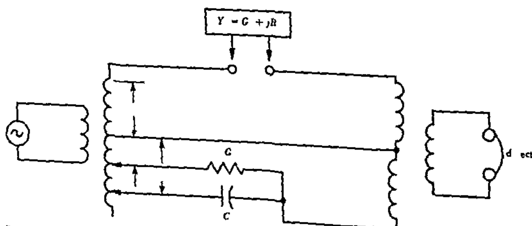


Fig 7 S mpl f d d ct t o-arm b dg

Combinations of switched fixed value tandards and continuously adjustable standards yield scales that are calibrated directly in conductance and capacitance independent of frequency Similar taps on the unknown side of the center tap are used to switch admittance ranges The in trument covers the frequency range from 15 kc to 5 Mc other versions extend the range from 15 kc to 250 Mc

Bridges of this kind are particularly well adapted to the measurement of the direct component of balanced and other three terminal admittances because the shunt components can be thrown across the low impedance transformer windings by grounding of the center tap and eliminated from the measurement They can also be adapted to the measurement of the transfer impedance of four terminal de ices

Boonton RX meter This bridge u es the same configuration of bridge arms as the General Radio bridge but measures the unknown as an admittance in the A arm rather than an impedance in the P arm For this inversion the balance equations become

$$G = \frac{C_N}{R_B}\left(\frac{1}{C_{P2}} - \frac{1}{C_{P1}}\right) \tag{27}$$

$$B = \omega(C_{A1} - C_{A2}) \tag{28}$$

The RX meter differs from conventional bridges in that the bridge arms are excited by out of phase voltages from a transformer At balance the junction point voltages are equal in magnitude but opposite in phase The null voltage is therefore obtained between the center point of a capacitive voltage divider and ground as shown in Fig 8

Microwave null devices At frequencies so high that the distributed nature of parameters must be

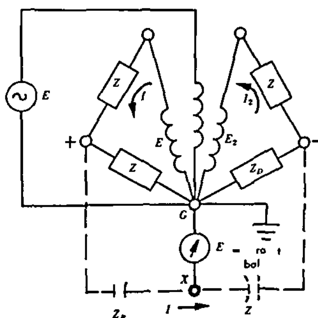


Fig 8 C cu t sch mat c of Boo to RX mete Sp cial th ee w d g t a sfo mer co ples o t-of phase olt ges f om the generat to the two h f e of the b dge a d th two capac tors Z_B a d Z p o de a ce te t p to f ed the d tecto

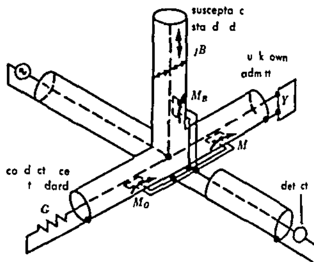


Fig 9 Funct onal d agram of General Rad o adm t tance meter The th ee loops M_B M_G and M sample the magnet c fields in the susceptance conductance and u k own adm tta ce a ms respect ely and com b e the outputs in the detector a m

taken into account the principle of null compari on can still be u ed to effect preci e adju tment There are three widely used commercial in truments for this frequency range

General Radio admittance meter This in trument hown in Figs 9 and 10 amples the magnetic field ari ing from the current in each of three coaxial transmis ion lines through adju table loops (M_B M_G and M) coupled to their center conductors at their junction point in the T configuration shown in the figure All the lines are fed at this point from a common voltage and thus the currents bear the ame relation hip to each other as the re pective admittances seen looking int each of the line One of the line i terminated in its characteri tic impedance Z_0 to pre ent a tand ard conductance G equal to $1/Z$ one is terminated in an eighth wa elength tran mi ion line to pre ent a standard susceptance B equal to $1/jZ_0$ and the thir l is terminated in the unknown admittance Y equal to $G + jB$ The coupling lo p can be rotated by mean of shaft carrying dial the fir t tw l eing calibrated in conductan e and su ceptance re pectively and the third in admittance range The lo p that c uple to the u cept ance line i adju tal le er a 180 range to indicate either po itive or negati e u ceptance tl e eigl th wa elength line i et to the proj er length for tl e operating frequency o that l th conductan e and su ceptance cale are direct reading in lep n lent of frequency If the unkn wn i conne ted t tl e in trument l y a ½ wave lin th reading of tl e e cale l ec me directly pr p rti nal t imj edan The in trument i dir t r a ling f r th freq n y range from 40 t 1000 M

Transfer fu ction an l imm tt brid A modificati n of tl e admittan e m t r mj ar tl e output current f a four t rminal d i e w th a lmit tance tandard in a T nfigurati n imilar t tl t descril d abo th r l y making po il l tl m a

u em nt of transfer adm ttanc by a null method Thro gh the u e of ½ wa e and ¼-wa t an m s-on l es in th inp t nd tput circu t it i po bl t mea u e the r ti f tp t current to input olt ge o tp t v lt ge t nput ur e t out p t t i put olta a d output to put curr nt A nt r ha geabl head c n rts the in t ume t t a adm tta e m ter making p ble mea ure-me t of t o-termin l dm ttan e ard imp d nc Th nst ument o r tl e f equency r nge from 25 to 1000 Mc

H ulett Pack d hf br dge In th i strument hown i Figs 11 a d 12 a apaciti e p obe m as-ures th le tric fi ld nd a nd cti e p be th m g t c field of oa i l l ne at th po nt t which it n ect to the nknown imped nce A g ged control adju ts the r lati e d gree of cou

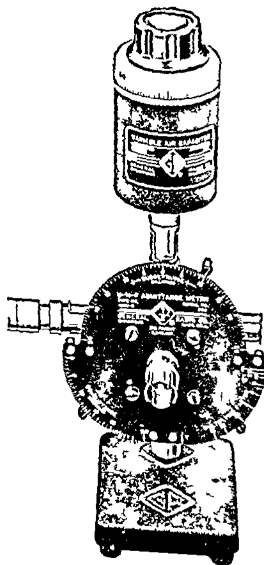


Fig 10 G l R d dm tt m t w h bl p it ect d o pt c d d (G l R d Co)

pl g of the tw probes and is calibrated to in l cat mped nce magnitude d rectly when the two i duced voltag s are equal The probe tputs are appl ed to the two end f a lott d l ne wh e xi lies in a circl about a point f om which a ear h p ob swing Th ign of the mutual ind ictanc of the inductive pr be i o cl o e that f r equal nduced olt ges the capaciti e and ind cti e ig nal c ncel at the center of the l tted line when th unk wn impedan e is purely resi tive Th d placement of th ea ch pr b fr m thi center positi n f r balanc s then proport nal t the pha e angle f any arb trary unknown impedance and a d al ttached t the shaft on which it i mounted s calibr ted in deg ees for a freq iency f 100 Mc At f equ ncies other than 100 Mc the read ng mu t b multiplied by the f equency in m gacy les nd d ded l y 100

Standing wave detector Sta d ng w e d tec tors ar dev c ed t mi r wa e freq i nc to mea re impedan es in terms of *electromagn ti* field d tr l tion in gu ded wave y tem

It is des r bl t make uch me urement with de ces of mple g met cal configurat n that th r perfo ma ce can be r ad ly analy ed n term f field theo y At the lower microwa fr q i nc es wher t an ve se dimen ons are m ll compared t th wa length the p rf rmance of co xial lines is ea y t compute a d thes de ices can b c nduc t ly on ected to irc its chara terized by two-te mi al on ect ons At the high r m cr wa e frequen ie wh re all d mensi ns are omparable with the w l ngth and th c nc pt f l mped r e e d t ibuted p m ters is no l nger re d l u abl wa e g i d ha e impl bound ry ndi t that fac litate c mput tio and v u l zat o of field d tr but n Th y b c ipled t th r wa e gu d s o to c tie thr ugh el ctric or mag net field rath r than with o d ti e nnect n *See* T A S I SSION LI ES WAVE GUIDE.

Impedance n be meas d with th e t n m s-n l ne by an ly f the b havio of electr c fi lds p opag t ng alo g the r xes In an deal z d o i l l ne o wa e gu de w th lo sle s, u ity d ele t c c sta t in ul ti n and perf ctly c n duct g w ll a plane wa e will p op gate along th ax s at th peed of l ght w thout alter t n long a th o s-sect n l d mens ns r ma n un fo m Th relati n h p b tween the ele tr c nd m g t fields w ll ma n sta t and b ca e th are respect ly p op rt n l t v ltag and curre t th at of the e fi ld w ll defin ha t t c imped n f the l

Whe th w r a h th nd f th tr mis s o l n a po t n det rmi ed by the mpedanc d s t nu ty t th t p nt i r fl t d backward t wa d th s e Th n dent nd fle ted wa e then add togeth t form a t tio ry nt rf c patt r ta d g w that has m xi a nd minima oc urr ng altern t ly at i t rvals f ¼ w v l ngth (s STA I G WAVE) Th m x ma ccur t th roi t t wh h the wa s r nf each th a d m a u the sum of th two m l

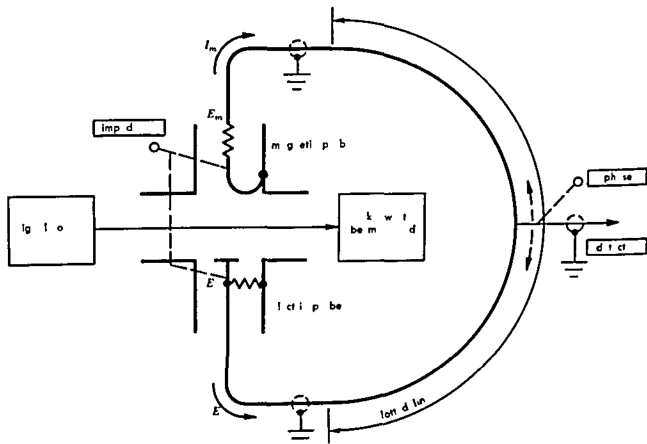
tudes the minima conversely measure their difference. The ratio of maximum to minimum voltage is *called the voltage standing wave ratio* (VSWR).

The amount of reflection depends upon the relation between the impedance in which the line is terminated and the characteristic impedance of the line. If the impedance is resistive and equal to the characteristic impedance, the current will flow into it just as it would into a further extension of the line itself and there is no reflection. If the transmission line is short circuited, the reflected voltage will be equal in magnitude but of reversed polarity to the incident wave because the net voltage must be zero at the termination. If the transmission line is open circuited, the reflected voltage will again be equal in magnitude but of like polarity to the incident wave so that the voltage doubles at the termination. When the terminating impedance equals the characteristic impedance, the VSWR is unity and the line is said to be matched. When the line is short circuited or open circuited the VSWR would be infinite if the line were lossless. The distance from the termination to the first minimum is respectively zero and ¼ wave length for these terminations.

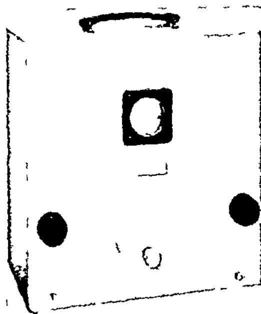
It can be shown that these two quantities, the VSWR and the distance to the first minimum, *uniquely define the terminating impedance*. They are easy to determine experimentally, but the mathematical conversion to the conventional impedance components is somewhat involved. Graphical methods of interpretation have therefore been developed and one known as the Smith chart is *in wide use both for determining impedance* from standing wave measurement and for analyzing the effects of finite lengths of connecting line.

Slotted line. A commercial slotted line for measuring impedance at the lower microwave frequencies is shown in Fig. 13. It comprises a cylindrical coaxial line having a slot in the outer conductor into which a small capacitive probe extends to sample the electric field. As the probe slides along the line its position can be measured to find the distance from the termination to the first voltage minimum and the maximum and minimum voltages determined to find the VSWR. This line is suitable for measurements from about 300 to 5000 Mc.

Slotted section. A commercial slotted section for measuring impedances at the higher microwave frequencies is shown in Fig. 14. It functions is similar to that of the coaxial slotted line but it differs in certain practical respects. Coaxial lines cover the frequency range from dc to the frequencies at which the higher order modes of propagation used in wave guides occur. Wave guides, on the other hand, are restricted to the relatively narrower frequency ranges over which a single selected dominant mode is useful. Replaceable slotted sections are therefore provided so that a wide frequency range can be covered with a single carriage mechanism. These various sections cover the frequency range from 2 600 Mc to 40 000 Mc with two models of carriage.



F... 11 ... d ag am of H wlett Pack rd hf b dge



Fg 12 H wl tt P k d hf b dge (H wlett-P ko d C)

Microwave reflectometer A reflect meter p-arates the i cident f refl cted wa es in a trans-m ion l ne and me ur their ind id ial ampli t de The rati of the e ampl tudes i equal to the m g ti de of the reflecti n coeff i nt $|\Gamma|$ f tl e t rminating impedanc The VSWR an be determined fr m

$$\text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|} \qquad (29)$$

To m a ure the term nat ng imped nce t elf an addit onal me ur ment f pha e hilt at the p i t of eflecti n neces ary The reflecti n coeff c ent an th n be rep e ented s a ect i l quantity $\Gamma/\underline{\theta}$ r lated to the term nat ng impe lan e Z_L a d the char cte i t c imped n e Z_0 of tl e tran mis-i n l ne by

$$\Gamma = \Gamma/\underline{\theta} = \frac{Z_L - Z}{Z_L + Z} \qquad (30)$$

f om wl ch

$$Z_L = \frac{\Gamma + 1}{\Gamma - 1} Z_0 \qquad (31)$$

A ba i ompo ent of th reflect m ter the d ection l o pler wh h pe f rm tl actual

Fig 13 Ge l Radio l tted l w th moto d l p id t m tic V WR d pl y (G l R d C)

Fig 14 Hewlett Packard slotted section for microwave measurements *Different wave-guide elements can be inserted in the carriage for different frequency ranges between 3 950 and 18 000 Mc (Hewlett Packard Co)*

separation of the two waves Two of these coupled to the transmission line in opposite directions yield independent measurements of the two waves from which their amplitude ratio can be computed A convenient arrangement uses a ratio meter to display the magnitude of reflection coefficient directly The angle θ of the reflection coefficient can be measured with an auxiliary slotted line to determine the distance from the termination to the first voltage minimum with an auxiliary capacitance probe to indicate the vector sum of the incident and reflected waves at a known point on the line or by *comparing the phases of the outputs of the directional couplers themselves*

A commercial instrument that performs a function *similar to the reflectometers is shown in* Figs 15 and 16

A rotating loop at a T junction couples to the magnetic fields of the three component arms which

Fig 15 Schematic representation of PRD standing wave indicator The detector loop shown can be rotated to vary its coupling with the magnetic fields generated by the currents in the T junction

are connected respectively to a susceptance standard the unknown admittance Y and a source of *rf power As the loop is rotated the induced voltage* varies between a value proportional to the sum of the currents in the standard and unknown arm $I_B + I$ *when it is aligned with the generator arm* and a value proportional to the difference of these currents $I_B - I$ when it is aligned with the other two arms For a setting of the susceptance standard that makes the arm admittance equal to $1/jZ_0$ the ratio of the minimum and maximum output which occur at settings spaced by 90 equals the VSWR It can also be shown that the angle of the loop at which the minimum occurs when measured from a 45 position between the generator and unknown

Fig 16 PRD standing wave indicator for impedance measurements from 30 to 1000 Mc *(Polytechnic Research and Development Co Inc)*

arm is equal to one half the angle of the reflection coefficient [D B S]

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r sonan e methods, *Pro IRE* 6(1?) 1466–14?7 1938 P H Smith T an mi sion li e calculator *El ctro ics* 1 (1) 29–31 1939

Impetigo

A c ntagi us ki d ea e comm nly s en n ch l d but al f und in ad lt It au ed by either tr ptoc al or t phyloc cal infe t ns o by both Th d as s aut in culable th t i it can be q kly p ead fr m an rig nal t to any part f the body No immu ty i c nferr d by exp ure S e STAPHYLOCOCCUS STREPTOCOCCUS

The les s r sup rficial th n walled bl ter wh ch r ay de el p i t pu t les These b me e ed w th a thi k adhe e t r t and the ur ro d ng k s red d tchy The face calp and extr mit e m t ften i l ed b t l ns may ppe r ywhe e in l din the m o s m mbra es f th eye and mouth

P d p g fa to n l d poor hyg ene in adequ t di t and wd d livi g c nd ti s In n ries mpet g m y qu kly l c me epid m c s nc th newborn a espe i lly u c pt bl

Imp t g f equ ntly f ll ws th r di o ders, p t l rly th e wh h p odu sev re it h g nd sub q e t r t h g u h a s abie nd ped u losi

Only r r ly is th d a e e s i s fa as mor t l ty i c n er d except i nfant T eatme t employ fr q nt le n ing nd lo al ant nfec t e g ts u h s the n w r nt l oti s S e ANTI BIOTIC. [E C S T]

Impsonite

A bla k n t lly o curr ng a bon eo*s mat ri l* h v ng pec fic gra ty 1 10–1 25 nd fix d a bo *0–8* Imp on t i inf bl a d s lubl in bo d lfid A ei f imp it 10 ft wid oc cu La Fl re County Oklahom and the e a the d po it n A k n s Nevad M h g n P A ge t na Br l nd Au t al a The Peru i n mp ite may be d ed from g ah *mite* by w ath g The o igi of mp o te i ot well n d r tood but t pp r to b d ed fr m a fl d b t m that p lym ed ft t filled the v n n h h t s f u d

Imp o tes e k wn t nta nu ually high P t ges f n d m S ALBERTITE ELATER ITE WIR ITE e *l* A H L A SPI L [I A B]

Impulse (mechanics)

Th t gr l of f n i t rv l of t me F r f F th mp l J r th nterv l f m *t* to *t* b w it

$$J = \int_{t_0} F\, dt$$

Th impul thu r p e nt th p du t f the time i t i l nd th a ag f a t ng d r ng the i t al Impulse ect q t ly w th th un*t of* m m t m

The m me tum mpul e relat n tate that tl e change n momentum o er a gi en time interval equals the impul e of tl e resultant force acting d ir ing that interval Tl s relation can b pro ed l y i t grati n f Newt n s econd law ver the time interval fr m *t* to *t* Let P repres nt the m mentum at time *t* with P and P_1 being the alu f P at t mes t_0 and *t* respecti ely Tl en

$$J = \int_{t_0} F\, dt = \int_{t_0} (dP/dt)\, dt$$
$$= \int_{P}^{P} dI = P_1 - P_0$$

If as s ordinar ly tru the ma *m* is c n t nt the m mentum change can be expres ed i terms of the velocitie v_1 a d v_0 at times t_1 and t_0 re pecti ely gi ing

$$J = m(v - v\ )$$

The co cept of mpul is ordina ly m t u ef l wl en the force are la ge b*ut act only for a hort* p r od I m t of the e ca es one needs t kn w nly th mom tum change wl ch i det m ned by the impul e Tl el ti n b twe *n moment* m a d imp l e tl u has the ad ant ge of el m nating the need f r detailed k wledge *of l ow tl e* fo ces wh ch can be very c mpli ated cha ge *with t m* For es wh h occur dur ng c ll i are f th t p S e C LLISION

A furth r mpl fic tio of th s type *of s*y tem i obta ned if th time *interv l* i shorte ough *for the* sy tem to be c de ed e ent ally tat nary d r ng the t me of act on of the f ce o th t the mo m nt m ha ge oc ur *almo t i* ta ta eou ly Fx *ept for the* cl anged m *mentum the* moti n of the *y t m i tre ted as t w uld h* been if no im p l e had o c r ed The effect f th impu l e can th i be c n d r d t pr ide a t of init l c n d ti *for the moti* In b llist c galvanom te fo e *mpl the e is* n el ct c rent *fo o ly* a hort t me *during* which the gal an mete c il r ginally at rest i g n n imp l e by the f e s oc at d w th th c e t The nly eff ct of th ur e t n th l i r *motio* f the il wh h can be o ide ed st t on ry d r *ng the t me th* re s rrent i t p o de n in ti l elo ity for the b- equent *m ti n* S G LVANO IETER IMPACT (IM PULSIVE FORCE) MO IENTU t [P W S]

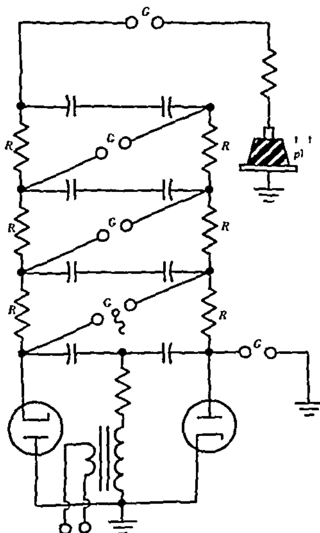
B bl og phy J W Campbell *A I t oductio t Mecha cs* d 194

Impulse generator

An l tr al pp ratus wh ch p d ce ery short rges f high lt g r *high current* pow r *H* gh imp l e volt g ed to t t the stre gth of i lators a d of p w r equ pment ag st pul a e prod ic d by th d sch rge of nden rs c ected n pa all l S h curr nt u g may b sed to m gn t p *rman nt* magnets or to p o- d e the r s ng r agnet c fi ld irculr p rt le c l r t s (se PARTICLE A CELERATO)

High voltage impulse generators commonly employ the principle originally suggested by E Marx of charging condensers in parallel and di charging them in erie The figure shows a four tage Marx circuit in which the conden ers C are first charged in parallel through charging resi tors R then connected in eries and di charged through the te t piece by the simultaneous sparkover of park gaps G The di charge is precipitated by placing a sufficient voltage on the middle elec trode of the three electrode gap between the fir t and second condenser banks

Although 1–2 × 10 volts (peak) is most common over 7 5 × 10 volts to ground have l een obtained The waveform shows a rapid ri e followed by a less rapid decline to zero expre ed by $v \propto (e^{-mt} - e^{-t})$ where v is the instantaneous voltage t seconds after onset of the di charge and m and n are the exponential decay constants of the circuit Typical indu trial laboratory waveforms are the 0 5 5 the 1–10 and the 1 5–40 in which the fir t numl er is the time in micro econds to the peak of the voltage wave and the econd is the time to one half voltage on the tail of the wave These di charges imulate the transient voltages induced in electrical conductors by natural lightning [J C R]



Typ cal fou -stage Ma x impuls g e ator ci cu t

Bibliography T E Allibone and F R Perry Standardization of impul e voltage te ting *J Inst Elec Engrs (London)* 78 257–284 1936 J D Craggs and J M Meek *High Voltage Laboratory Technique* 1954 F Marx Inve tigation in the testing of insulators with impact voltage *Elektrotech Z* 45 652 1924

Impulse turbine

A prime mover in which fluid under pre ure enters a nozzle where its pre sure (potential energy) is converted to velocity (kinetic energy) the fluid then impinges on blades of a rotor imparting it energy to the blades to produce rotation (see TURBINE) The fluid may be water steam or h t gas (see HYDRAULIC TURBINE STEAM TURBINE TURBINE PROPULSION) The action i continuou thus a de ignation such as pre urele s would be more descriptive although impulse is e tabli hed by long usage See PELTON WHEEL see also REACTION TURBINE [F H R]

IMViC test

A mnemonic for a group of four cultural te t u ed to differentiate genera of bacteria within the family Enterobacteriaceae The e te t are de cribed in the following paragraphs

Indole This is a putrefactive compound produced by some l acteria from tryptophan The l acteria are inoculated into a broth made with an enzymatic dige t of ca ein (see CASEIN) After a 2 hour incul ation at 37 C a oluti n c mp o ed of *para* dimethylaminobenzaldehyde amyl alcohol and hydrochloric aci l i added A p o itive reacti n is the appearance of a red color in the alcohol layer indicating tl e p re ence f ind le

Methyl red This i a te t f r the ability of certain l acteria to ferment carl ohydrate and form acid The pH of a culture containing 0 5% gluco e is determined after 4 day at 37 C If the pH is below 4 5 (tl e pH at which the indicat r methyl red turn red) the micr organi m i termed methyl red po iti e

Voges Proskauer Thi i a qualitati e te t for tl e formation of acetyl methyl arl in l fr m glu co e A large ino ulum of tl e rgani m under study i made into a tul e of gluc e l r th incu bated f r (hour at 30 C S l ti n f α naphthol pota ium hydroxide an l reatine are a l led t tl e culture A p itive rea ti n i in li ated l y a pink t r e l r

Citrate Tl i i a te t f r the al ility f an r gani m to utilize odium citrat a a le source f c rbon A me lium i p repar l with p t ium dil y lrogen pho phate (KH P O) magne i m ul fate (MgSO) sodi um ami ni m pl o phate (NaNH HPO) and s l m cit ate (Na C H O) in li till d wat r A small in c l m f the or gani m is u d in th me lium After inc l ati n gr wtl of tl e in c lum in licat citrate utiliz ti

Th f ll w ng re tion patte n a e on dered typ l f r the m re mp tant g nera of E tero- b te acea

(	I d l	M thyl ed	V ges- Prosk	C trate
E h tchia	±	+	−	−
A robacle	±	−	+	+
Prot us	±	+	−	±
Salmo ll	−	+	−	+
Shig l		+	−	−

± d t ti th be pos t gat

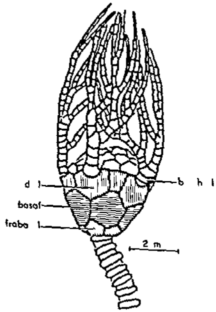
Th a e h w e m ny e c ption f om tand d hi h e e ely e t ct the t o om a d di g t c l e of thi t f test *Se* BACTER OLOGY MEDICAL CULTURE TECHNIQUE

[A J W]

B bl g phy So ty f Ame a B t r lo- g st *M n l f M b l gi l M th ds* 1957

Inadunata

An t ct b la f talk d C in dea e mpris- ng m 00 I al ge ra angi g fr m th Upp Cambr an (Tr mad an) to th P *mi n*



A d g m f Cy th d cy l d te d h w g th m pl t (Aft F B th 1900)

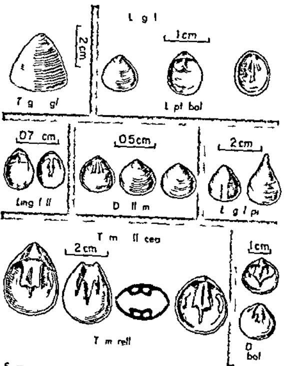
Th m (3-5 o mo e) w mpl tely f e nd i n w y n po ted i t th alyx Th y w r the b n hed mple d omet m bor p n les Th m th a d ml lacral gr o s w u u lly oofed o by e s of mall pl t a d tl t gm n wa i d by pl te Th lyx wa th r m ocy li r d cycl c w th c n picu d l nd b sal nd all th th c l pl tes e tu ed t g th r int g d y t m I som f m

the an s lay at the upper end of a l ng plated ph n r s ng f om the tegmen The gr up contains the oldest ecognizable cr noid *De d ocr us* fr m the Tr madoc an of Wale *See* CRI OIDEA

[H B F]

Inarticulata

A cla s of the phylum Brachi p da characteriz d by ha ng n art culati g pro e e u h a *teeth* and sock ts al ng the c rdinal ma g n or hinge



S m p t t s f art c lat B h pod (F m R C M C G L I k d A G F ch I rt b t F l M G w-H ll 1952)

I or if pr t th y re r diment ry Th tw l a e op n d and lo d by muscle ct n nly Tw de s a recog ed the Atremata and Neo- t emata A arti ulati n a ly fu ct al ı *Sp dyl b lus* and *T m lla* both m mbe s of th In rt ulat and ha dly f n t n l n *A t g na* nd *S hizophalus* wh ch a e A t c l ta a comm n r g for both gr ups s sugge ted The Inart c lata a g f on the Camb n to Recent [K H]

Incandescence

The em s on of i ble r d t o by a l t body ı th etically perfect ad t ll d a bl k l dy will m t d a t ene gy rd ng t Pl nck radi t on l w t a y temper t e P di t o f tl ı u l b ghtn s q es add ti nal con ide t o f th e tiv ty of th ye and the rad t n w ll be ı bl ly f t mp atu of th bla k b dy wh h abov me m n m m The elat n l twe b gl tne s a d t mp r tu e ı pl tted ı th fig e A h wn th mi m m t mp at r for ı d cenc f the d rk ad j ted eye bo t

Relat on between br ghtness of a black body a d tem pe atu e

Approximate color temperatures of common light sources

So c	Color t mpe at e K
Ca ll	19
K ro in l n p	000
Con t gst n fl ment 100	
w tt l t l gl t l lb	800
C rbon	4000
S	800

390 C Under the e ideal ol erving condition the incande cence appears a a cclorle glow The dull red light commonly a cciated with incande cence of ol ject in a lighted ro m requires a tem perature of al out 500 C *See* BLACK BODY HEAT RADIATION VISION

Not all ource of ligl t are incande cent A cold gas under electrical excitati n may emit light a in the o-called ne n tul e or tl e l w pre ure mercury vapor lamp Ultravi let light from mercury vapor may excite vi il le light fr m a cold c lid as in the fluore cent lamp Lumine cence i the term u e l to refer t tl e emi i n of light due to cau e c ther than high temperature and include thermolumi ne cence in whi h emi i n f previ u ly trapped energy occur on moderate heating See THERMO LUMINE CENCE *see also* FLUORESCENT LAMP MER CURY VAPOR LAMP

Flame are made luminou l y incande ent par ticle of carl on (a flame can l e made to pr luce inten e light l y tl e u e of a ga mantl of thoria c ntaining a mall am unt of ceria Tl i mantle i a good emitter of vi il le light l ut a poor emitter f infrared ra liati n A les heat i l t in the long wa e the mantle operate at a high r temperatur than a l lack body w uld and hence produce m re inten e vi il le light

A u ful criterion of an incande cent o irce i it c l r temperature the temperature at wl ich a black body has the ame color although not neces arily the ame l rightne The color temperature of common light ources depend upon operating condition Approximate value are given in the accompanying table *See* COLOR TEMPERATURE INCANDESCENT LAMP [H W R]

Bibliography M M Benarie Optical pyr metry below red heat *J Opt Soc Am* 47 1005–1009 1957

Incandescent lamp

An electric lamp that produces light by heating a metallic filament to inten e heat by pa ing an electric current through it It is de igned to pro duce light in the vi ible portion (at wavelengths of 380–760 millimicron) of the electromagnetic pectrum The filament i prepared of pecial ma terials and is enclo ed in either an evacuated en clo ure or one filled with an inert gas In addition to radiation in the vi ible spectrum infrared and ultraviolet energy are emitted thus lowering the luminou efficiency of the lamp When either of the e radiation is accentuated however the lamp may be u ed as a ource of that radiant energy The light source efficacy formerly called light ource efficiency i expre ed in lumens per watt Luminous efficiency is the ratio of the luminou flux to the radiant flux

Lamp construction The important part of an incande cent lamp are the lamp enclo ure or l ulb the filament and the ba e The e and the auxiliary parts of a typical incande cent lamp are hown in Fig 1

Standard lamps have vari us bulb hape ba e and filament con tructi n The l ulb may l e clear colored in ide fro ted or coate l with dif fu ing or reflecting material Mo t lamps have soft gla l ulb hard gla i u ed when the lamp will l e ul jected to udden and severe temperature change In a l liti n lamp are availal le with a variety of l ulb hape l a e type and filament tructure a h wn in Fig 2 The e ary accor l ing to the type of service planned the nee l for

Fig 1 Pa t of the i ca d c t l mp (G l El c tr c Co)

( )

d k
med m
pr foc
mog l
p foc
med m
b po
mog l
b po t
t l ph
l'd
2 pi
m
PAR
l de-prong

PAR
scr w ba
(b)
PAR
screw rm l
m
rm d at
dmed m
(m rc ry l mp)
mog l
m t
bayo t
bay t
d l b
d l b
med m
3 l
k rted
m
fl ged
bay t
d l b
p foc g
coll

y y y y ba d w ba dow base dow y y a y

( ) y y y base y ba dow y ba p base d w y

Fig 2 V ia f l d sc t l mp ( ) B lb sh pe (b) L mp base ( ) Fl m t tr t (give b rn g po io) (G l El ct C)

easy replacement and other environmental and ervice conditic n

The efficient de ign of an incande cent lamp centers about obtaining a high *temperature at the filament* without the lo of heat or di integration of the filament The early selection of carbon which ha the hi he t *melting point of any element (6510 F)* was a natural one Carbon evaporates from it olid pha e (sublimate) below this temperature howe er and it must be operated at relatively low temperatures to obtain reasonable life Two other elements o mium (melting point 4890 F) and tantalum (melting point 5250 F) claimed attention l ecau e they could be operated at a high temperature *with a longer life and le s* evaporation With the advent of ductile tung ten a nearly perfect filament material was discovered Ductile tungsten has a tensile strength four times *that* of teel its melting point is high (6120 F) and it has relatively low evaporation Hot tung ten is an efficient light radiator it has a continuous spectrum clo ely following that of a l lack body radiator with a relatively high portion of the radiation in the visible spectrum Becau e of its strength ductility and workability it may be formed into coil the e coils again recoiled (for coil coil filaments) and the e again recoiled for cathodes in fluorescent lamp If tungsten could be held at its melting point 52 lumen/watt would be radiated *Becau e of physical limitations* howe er 22 lumen/watt is the highest practical radiation for general service lamps ome special lamps reach 35 8 lumen/watt The higher the lumen per watt the higher the filament temperature and the color temperature and the whiter the light

Because the temperature of the filament c ntrol the life of the lamp and its efficiency it al o controls the economic of lighting For an economical installation the factors affecting lamp life are weighed again t the c t of the lamp and it in*stallation and the cost of operation This type of* economic study however is rarely made of a lighting in tallation The usual practice i to select a de ired lamp ize from the tock of the sup plier for the accepted regional voltage

Vaporization of the filament i reduced a mi ch as po ible A mall amount remain howe er and cau e blackening of the l ulb The evaporated *tung ten particles are carried to tl e upper part of* the bull by con ecti n current With the lamp in a base-up position the blackening is c nf ned to the ocket area and the light output i nly lightly *affected In a l a e down p sition the l lackening* reduces the output a few per cent To reduce blackening the inner atmo phere of the lamp is kept as clean as po il le by i e of a getter which combines chemically with the tung ten particle In lamps in which a getter i not adequat tung sten powder is enclo ed in the bull and u d t cour the urface l y haking In me lamp a grid i placed to attract and h ld the evap rated tung ten particle

When cement failures are likel becau of tl e l eat *m* hanical fa tening i u ed to h ld tl e l a to the gla s When large electric currents are present either mechanical fa tening or bipo t construction is u ed Bipo t and prefocus ba e allow accurate placement of the filament with re pect to the equipment for which it is de igned There are two common failures of the lamp bulb (1) in projectors *when the filament image is focu ed upon* the gla s and the bulb bli ters and (2) when the hot bulb comes in contact with some low temperature medium and thermal cracks develop To protect the electric circuit *from ome lamp failure* a fu e may be placed in the lead in wire

Lamp ratings Lamps are built for variou volt age conditions the most common being 115 120 *and* 125 volts High voltage lamps are designed for ratings from 220 to 260 volts and low voltage lamp from 6 to 64 volts Lamps for u e in 525 to 625

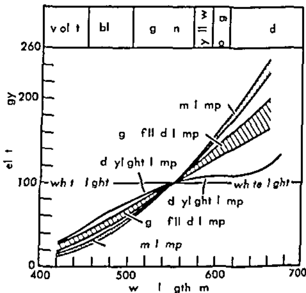


Fig 3 Sp ctral e e gy d str but o for Important typ of inca d cent lamp

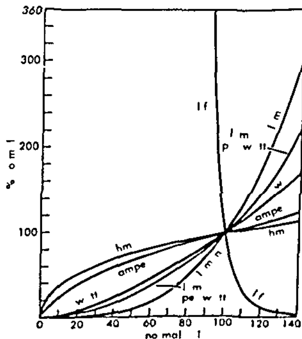


Fig 4 Cha act t c c rv fo i cand sc t l mp

lt y tems desi ed to *operate in gr ups* f fi in ries acro th l n Ch i tma tr e l hts ar designed to perate in parallel r n r s with e gl t l mp placed acr the l n St et l mp re f the e ie typ per tin n 6 6 amp e ept i e systems wl er ndi id al lamp tran f rmer a u ed w th lamp urrent of 15– 0 amp In se ies t t lighting y tem tl e nti nu ty f the electr al yst m i ma ta ned by a de ce that sh t c cu ts the lamp wl n the fila ment b r t

Lamp characteristics Tw hara t ri ti f the ca d c nt lamp f parti ul int re t a e p t and of Fi e 3 h ws the el t n y n th ari u c l r gi n for the major type of ca de e t l mp F gur 4 sh w the h ge f the r u per t ng ch racte st s th cha ge of ltage

At time it i ee a y to d t m ne l mp cha a t r t c u de th r than rm l co d ti Th f llowing fi e ts f qu t o with xpon nt g n Tabl 1 pe m t s lut on f r actual ervice d t mpa ed t n rmal op rat

$$\frac{\text{l fe}}{\text{LIFE}} = \left(\frac{\text{LUMENS}}{\text{lum}}\right) = \left(\frac{\text{LUMENS/WATT}}{\text{l m /watt}}\right)^{s}$$

$$= \left(\frac{\text{VOLTS}}{\text{lts}}\right) = \left(\frac{\text{AMPERES}}{\text{mpe e}}\right)$$

$$\frac{\text{l m}}{\text{LUMENS}} = \left(\frac{\text{v lt}}{\text{VOLTS}}\right)^{k} = \left(\frac{\text{l m n /w tt}}{\text{LUMENS/WATT}}\right)$$

$$= \left(\frac{\text{tt}}{\text{WATTS}}\right) = \left(\frac{\text{mpe es}}{\text{AMPERES}}\right)$$

$$= \left(\frac{\text{hm}}{\text{OHMS}}\right)$$

$$\frac{\text{LUMENS WATT}}{\text{l m tt}} = \left(\frac{\text{LUMENS}}{\text{l m n}}\right)^{f} = \left(\frac{\text{VOLTS}}{\text{lts}}\right)$$

$$= \left(\frac{\text{AMPERES}}{\text{mpe e}}\right)^{t}$$

$$\frac{\text{ampe}}{\text{AMPERES}} = \left(\frac{\text{lt}}{\text{VOLTS}}\right) \qquad \frac{\text{w tt}}{\text{WATTS}} = \left(\frac{\text{lts}}{\text{VOLTS}}\right)$$

T th q t it ry fi t t k w th m l har t t f the l mp u h l fe lume l m n p watt lt mp re watt l hm f ll th h t t to b tud ed d b m l lt n S b t t t g to th t t th pe fi m l h te t (up pe c l it) a d th pe l dit s (l w l it) w th the p p ponent f om Table l tl k w ch t t m y be det m ed Th pe t T bl 1 e f d at t m b t f p t l pu p se d f r orm l ltag a g th g ll uffi

T l l g es tl ff t p tag f p rat ng f nt l mp l el w mal lt g Al th gh l w lt ge d se c lamp lif th ec m fi f l gl t ad g t u h p t

Applications and special types In nd t l m l l d l ted f m y r ce M t om m th ed t g l r a d th m t t t e l mp Spec al type l a e b en de el ped f ugh rvi e ppl cat n b ke o en us s v re br t ppl c tio h w a e lamp m lt ple l ght (th e w y lamp) gn lamps potl ght fl dl ghts and i ect ntr l lamps

Se e st e t light g lamps are de ign d w th hea y fil m nt Th c it p at s at a nst nt ur ent a d the oltag on the c r uit s adju ted t th n mb r f b rn g lamp s t ke p th u e t t t

R flect r type l mps ha th l ght c t l b ilt t the de g f the lamp Th is do e by out id l e ng w th the l er ng pl ced n any des d gi n f th lamp fac The r fle ti g face p tect d a d effe ti e for the l f of the l mp

Proj t typ l mp h ve m ld d gla fle t il e ed i d the l n p ty w th th r a l a gl s co m ld d trol le ver The refl t *a d th* o e a *sealed* t g th r f m ng l mp with n te al refl t The parts e f h rd gl s d th lamps may b d f r tdon rvi in floodl gl t a d p tl ght i tall *n s Th al th* typ f l mp u d in the led be m h dlight f a tom b l l mo-

Table 1 Exponents

	G filled	V
	3 86	3 8
b	1	7 0
d	13 1	13
	1 1	3 3
k	3 38	3 1
h	1 81	1 8
	19	
y	6	6 0
	7 36	8 36
f	0 541	0 5 0
g	1 81	1 93
j	3 40	3 33
l	0 541	0 580
	1 54	1 58

T bl 2 Typ l performan e f l ge l a d c t lamp b ed below r ted lt g

P ce t g f m l pe t			
V lt g	Light tp t	W tts	Effi y
100 0	100 0	100 0	100 0
99	97 3	98 8	98
98 3	94 4	9 4	96 9
97	91 8	96 1	9 4
96 7	89	9 0	93 8
9 8	86 4	93 6	9 3
9 0	84 0	9 4	90 8
94	81 5	91	89 4
93 3	8 0	89 8	8 7
9 5	76 6	88 7	86
91 7	4 1	87 5	84 8
90 0	69 5	8 0	81 7
88 3	6 0	8 5	79 4
86	60 8	80 3	8
8 0	56 6	77 9	72 8
83 3	5 0	5	69 7

ea y replacement and other environmental and ervice conditions

The efficient de ign of an incande cent lamp cen ters about obtaining a high temperature at the fila ment without the lo s of heat or di integration of the filament The early election of carbon which has the highe t melting point of any element (6510 F) wa a natural one Carlon evaporate from it olid pha e (ublimate) belcw this tem perature however and it mu t l e operated at rel atively low temperatures to oltain rea onable life Two ther element o mium (melting point 4890 F) and tantalum (melting point 5?50 F) claimed attention becau e they *could be operated* at a high temperature with a longer life and le s evaporation With the advent of ductile tung ten a nearly perfect filament material was discovered Ductile tung ten has a ten ile trength f ur time that of teel it melting point is high (6120 F) and it ha relatively low evaporation Hot tung ten i an efficient light radiator it ha a continuous spectrum clo ely fllowing that of a l lack l ody radiator with a relatively high portion of the radia tion in the vi ible pectrum Becau e of it trength ductility and workability it may be formed into coil the e coils again recoiled (fcr coil coil fila ments) and the e again recoiled for cathode in fluore cent lamp If tungsten could be held at its melting point 52 lumen/watt would be radiated Becau e of phy ical limitations however 22 *lumen/watt i the highe t pra tical radiation for* general ervice lamps ome special lamps reach 35 8 lumen/watt The higher the lumen per watt the higher the filament temperature and the color temperature and the whiter the light

Becau e the temperature of the filament controls the life of the lamp and it efficiency it al o c n trols the economics of lighting For an economical in tallati n the factor affecting lamp life are weighed again t the c t of the lamp and it in tallation and the co t of operation Thi type of economic tudy however i rarely made of a light ing in tallation The u ual practice is to select a de ire l lamp size from the tock of the upplier for the accepted regional voltage

Vaporizati n of the f lament i reduced a much a po ible A mall amount remain however and cau e blackening of the l ull The evap rated tung ten particle are carried to th upp r part of the l ull l y convecti n current With the lamp in a l a e up po ition the l lackening i nfined to tl socket area and the light output is nly lightly affected In a l a e down p ition the l la kening *reduce the output a few per cent* To reduce l lackening the inner atm phere f the lamp i kept a clean a p ible l y u e of a g tter which c mbine chemically with the tung t n particle In lamp in which a getter i not adequat tung t n p wder i enclo d in th l ill and u ed to c ur the urface l y *l aking In om* lamp a grid i placed t attract and h ld the e ap rated tung ten particle

Wh n cem nt f ilure ar likely becau e of the h at me hani l fa t ni g i u d to h ld the l ase to the gla When large electric current are pres ent either mechanical fa tening or lipc t con *truction i u ed Bipo t and prefocu l a e all* accurate placement of the filament with respect to the equipment for which it is de igned There are two common failures of the lamp l ulb (1) in pro jectors when the filament image is f cu ed upon the gla s and the bulb l li ters and (2) when the hot bulb comes in contact with some low tempera ture medium and thermal crack devel p To pro tect the electric circuit from ome lamp failure a fu e may be pla ed in the lead in wire

Lamp ratings Lamps are l uilt for various v lt *age conditi n the mo t common l eing* 115 120 and 125 volts High voltage lamps are designed for ratings from 220 to 260 volts and low voltage lamp from 6 to 64 volts Lamps for u e in 595 to 625

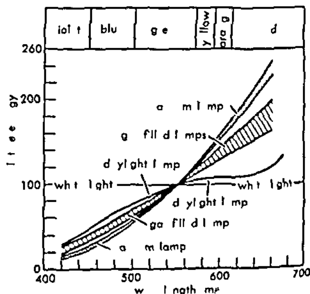


Fig 3 Spect al e e gy d st but on for importa t types of i cand cent lamp

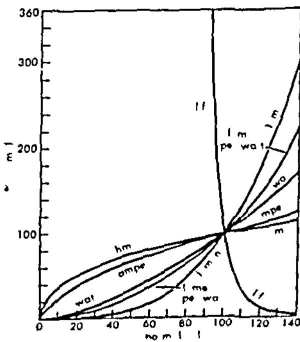


Fig 4 Ch act i t c c rv fo l a d t l mp

It ystem are des gned t ope ate in group of fi e n erie cro s the l n Chr tm a tr e lights ar des gned to op at in parall l r in s r es with ght f mps pla ed acro the l ne Str et lamp ar of the e es typ operat ng n 6 6 amp ex ept in e y tem whe e i di dual lamp t a sform s ar u ed w th lamp cu r nt f 15-20 amp In a r es t eet l ghti g syst m th t n tv f th elect cal system s m inta ned by a de ice that h t-cir u t th lamp when tl e fil ment b rn out

Lamp characteristics Two ch racte t s f th in and t l mp of p rt c l r i te e t a e pe t on and ol r Figur 3 hows the el t e gy the atio s c l r r g on for the majo typ of i and t lamp Figu 4 h w the ch g f the var i p at g character tic with a cha of lt ge

At t m t is ne ary t d t rmi l mp ch r t tics u d r th r th n mal c diti Th follo g fi e t of eq ati n w th e ponents gi n Tabl 1 pe mit luti f r a t l erv ce co d ti ns a mpar d to n rmal op rati

$$\frac{\text{l fe}}{LIFE} = \left(\frac{\text{LUMENS}}{\text{l m s}}\right) = \left(\frac{\text{LUMENS/WATT}}{\text{lum ns/w tt}}\right)^{s}$$

$$= \left(\frac{\text{VOLTS}}{\text{olts}}\right) = \left(\frac{\text{AMPERES}}{\text{mpe es}}\right)$$

$$\frac{\text{lum}}{\text{LUMENS}} = \left(\frac{\text{lt}}{\text{VOLTS}}\right)^{k} = \left(\frac{\text{l me /watt}}{\text{LUMENS/WATT}}\right)^{k}$$

$$= \left(\frac{\text{tts}}{\text{WATTS}}\right) = \left(\frac{\text{ampe s}}{\text{AMPERES}}\right)$$

$$= \left(\frac{\text{hms}}{\text{OHMS}}\right)$$

$$\frac{\text{LUMENS WATT}}{\text{l m n att}} = \left(\frac{\text{LUMENS}}{\text{lum ns}}\right)^{f} = \left(\frac{\text{VOLTS}}{\text{olts}}\right)$$

$$= \left(\frac{\text{AMPERES}}{\text{amper}}\right)$$

$$\frac{\text{mpe s}}{\text{AMPERES}} = \left(\frac{\text{lt}}{\text{VOLTS}}\right) \qquad \frac{\text{watts}}{\text{WATTS}} = \left(\frac{\text{volt}}{\text{VOLTS}}\right)$$

T th q t o t ne es ar fir t to kn w th n mal h r t t f th l mp u h l fe l l m p watt l mp watt a d hm if ll th ch ra t t r t be tud d und b m l o d t Sub t tuti g t t the q t the i fi n m l ha t ti (p- pe -c l tt) and th p l d t (l we l tt) tl th p pe e p n t f m Tal l l th u k n l a te t m y be d te m ned Th e po t n Tabl l a ch ged t t me but f p t l p p e d f r rm l ltage ge th se g n will uff

T bl g th ffect p entag f p t ng d nt l mp bel w n m l v lt g Al th gh l w lt g d e a l mp l fe th eco m a fie f l gl t d es agan t u h p tt

Applications and special types I a des nt l mp ha bee dev l ped f m ny rv e M t omm a th ed g l ers nd the

Tabl 1 Expon nt

	C s-filled	V m
	3 86	3 8
b	7 1	7 0
d	13 1	13 5
u	1 1	3 3
k	3 38	3 51
h	1 84	1 8
	19	
y	6	6 0
	7 36	8 36
f	0 41	0 5 0
g	1 84	1 93
j	3 40	3 33
l	0 41	0 580
	1 54	1 58

Tabl 2 Typ cal perform f la g i ca d sce t l mps burned below ted voltag

P	tag f	rm l pe t	
V lt g	Light tp t	W tt	Eff y
100 0	100 0	100 0	100 0
99	97 3	98 8	98
98 3	94 4	9 4	96 9
9 5	91 8	96 1	9 4
96 7	89..	9 0	93 8
95 8	86 4	93 6	9 3
9 0	84 0	9 4	90 8
91	81 5	91	89 4
93 3	8 0	89 8	8
9 5	6 6	88 7	86
91	74 1	87 5	84 8
90 0	69 5	8 0	81 7
88 3	6 0	8 5	9 4
86	60 8	80 3	8
8 0	56 6	77 9	8
83 3	5 0	7 5	69

m atu e l mp Spec al t pe h e b en de l ped for o gh erv e ppl cat n b ke-o n u e e brat n ppl c t on sl we e lamp mult ple light (thr e w y l mp) gn lamps p tlight fl dl ght nd n ect co t l l mp

Ser tr t l ghtin lamps re des gn d w th h a y flam nt The cu t je t s at con tant r at d the oltage on the c r uit i adju ted t the umbe of bu ng l mps s as t k ep th c e t consta t

R flect typ lamps ha the light ontrol l u lt into the de gn f th lamp Th s d ne by t d l g w th th l e g plac d on any de r d regi of the lamp s rf c The reflect ng urf c i p te ted a d effect for the l f f th lamp

P oject r type l mp l a molded gla s refle to s th d n ide th l mp ca ty with ither a cl a gl s co r a m lded control l n co er The fi t and the co er ar led t gether fo mi g a lam p with nt in l refl tor The p ts re f ha d gl s nd the lamp m y be u d fo o td r rvi e in floodlight a d potl ght i talla t Thi al th type of l mp ed n the led b am h adl ght f a tomob l s lo mo-

tives and airplanes A high degree of accuracy—just short of optical accuracy—is achieved by molding the contours of the reflector thereby ob taining accurate beam control With this turdy tructure the filament can be positioned for the best u e of the lens and the lamp has little depreciation during its life Being constructed of hard glass it lends itself to high wattage use

Miniature incande cent lamps are used in many fields and in many pieces of equipment from the ordinary fla hlight to the grain of wheat lamps used in surgical and dental in truments The e lamps are de igned to give the highest efficiency con istent with the nature of the power ource em ployed

Special picture projection lamps are de igned for accurate filament location in the focal plane of the optical system with the filament concen trated as much as possible in a single plane and in a small area The e preci ion lamps u e a prefocus base for accurate po itioning of the filament with re pect to the ba e Projector lamps run at high temperatures and forced ventilation is frequently required

A special class of lamp is designed for the photographic field where the chief requirement is ac tinic quality Frequently the most important rating is the color temperature with little regard for eco nomic efficiency or life I hotoflood lamps give high illumination for a short life obtaining twice the lumens from high filament temperature and high color temperature with three times the photo graphic effectivene s The daylight blue photo flood lamp gives a very white light at 4800 K color temperature at 35 8 lumen/watt

For other types of incande cent lamps *see* ARC LAMP INFRARED LAMP [J O K]

Bibliography Illuminating Engineering Society *IES Lighting Handbook* 3d ed 1959

Incendiary

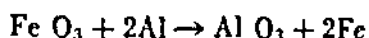
One of a number of flammable materials and de vice that are u ed to et fire to tactical and strate gic target such a buildings industrial in talla tion and fuel and ammunition dumps Flame war fare extend al o to antip er onnel u e in the ca e of flame thr wer and f re boml s

Modern incendiarie can l e cla ified a either tho e which owe their effect t a elf upporting chemical reaction or th e wl ich depend on atmo pheric oxygen t support coml ustion



M ch zed fl me th ow r

Metallic incendiaries Thermite is a mixture of powdered iron oxide Fe_2O_3 and powdered or granular aluminum When heated the following reaction occurs



$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$$

This produces a temperature of about 2?00 C and melts the iron formed which in turn easily ignites any combustible material with which it is in con tact The reaction is elf sustaining

Metallic magne ium igniting at about 600 C, requires oxygen to support combu tion Once tarted the fire is extremely difficult to put out Water is decompo ed by burning magnesium and adds hydrogen to the combustion Burning i topped only by excluding oxygen or by cooling the metal below its ignition temperature Incendiary bomb ca ing of magnesium are usually ignited by a thermite core

Petroleum incendiaries The e are ba ed on gasoline as a fuel The gasoline may be either straight or mixed with other petroleum fuels It must however be thickened to be an effective in cendiary This thickening is nece ary to confine the burning material to the target and when u ed in flame throwers to increa e the range of the ejected rod of fuel and to prevent its l eing con sumed before reaching the target Thickened fuel is ometimes called jellied ga oline

One of the fir t practical fuel thickeners was Napalm a mixed aluminum oap in which the organic acids are derived from coconut oil (50%) naphthenic acid (25%) and oleic acid (? %) It may be u ed in quantities ranging from 1 to 12% depending on the thickne s de ired Ga oline thickened with Napalm l ecome a firm jelly when undi turl e l but in motion such a when force l through a flame thrower nozzle it acts as a vi cou liquid This thixotropy i characteri tic of all thickened fuels

Flame throwers are devices which force petr leum fuels through nozzles igniting them a they emerge The driving force is u ually compre ed air carried in a mall tank which i an integral part of the device Portal le flame throwers carrie l by soldiers have a range of over 50 yards under i l al condition Mecl aniz d flame thr wers mounted on military vehicles can thr w fuel o er 150 yard Flame thr wer are primarily antip rsonnel weapons

Other incendiaries White ph phoru which ignites sp ntane u ly in th pre n of atm pheric oxyg n to produce a d n lou l f pl ph ru pent xi le ha l en n i l re l l y me a an incendiary alth igh it principal u l a l e n a a sm ke producer Bur ting l ll r gr n les th r w i g mall drops of l rning whit pl p oru l a l n eff cti e a antip r nnel inc n liarie S CHEMICAL WARFARE FIRE EXTINGUISHER SCREEN ING SMOKE [S D]

Bibl og aphy C org J B Fi l r *Inc* f y *W a fare* 19? U S D partm nt f tl Army *Mili tary Ch mi try a d Ch mi al Ag t* T hni l Man ial TM 3 15 Aug i t 19?

Inclined plane

A pl n urfa ncl ned at an a gl with th l ne f cti n of th force th t i t b exerted o o e m Th u al applicat n i illustrat d i the

P p l f ( ) we ght n g o i In d pl d the lut t m l f c (b)

d agr m A l ti ely m ll force cti g parallel to the rf c h lds n object in pl e or mo es it at c n t nt peed

In th f ee-body d agram th e f es act o the object when n f i ti n s p e t The f es a e t w ght W the f e F p r llel to the urf c d a f r F m l to th u fa e Th umma ti n of th f es a t g n a y d e t a body in st tic eq l b m equ l e the ef r th mmat o f f par llel t and forces n rmal t the s rfa e a e

$$F - W \sin\theta = 0$$
$$F - W \cos\theta = 0$$

A fo c l ghtly g t tha W n θ mo e th b- ject p th in l e, but th i l ned plane pp rts th g t p rt f th we ght f the l ject. The p pal e f th l ed pl ne a amp for m ng good fr m o e lev l t a the Wheels ma be dded t th bje t t b a ed t decr e f t n but th p e ple r ma th ame Th edg nd sc w r l ely el ted t the in l ned pl n nd f d wid appl t n S SIMPLE MACHINE [R M FH]

Inclinometer

A n t m t fo m g m gn t d p r i In t wh h defi d th a gle b tw n the m gn t fi ld t nd th h ntal pl ne l th f m f impl d p n dle th in tru m t th p ted merh n ll b la ed bar m gnet m u ted h r i l b g Wh n o ted so th t t pl e of t ti n n the m g t m d n th eedl l gn it ll w th the d ect f the m gnet fi ld a d ndi ate n cul r al the gle f d p It s u d p n pally mi n y g wh e th mi l ha e high oi t f m g t m t ial

Th d p i l lso es b l n ed eedle b t of fi i t n nd p o ded with ac u ately g d nd poli hed nd halt be r ng h n t l gat pl tes Th d recti n f m gn t zat on f h edl rtifi ally e ed e al t mes d g eet f b rvat n to ed e th res d l eff ct of mechan cal unbalance and the positi ns of the ends of the needles a e read with micro- scope mou ted n a verni r equipped vertical cir cle Th d p circle having an ac u acy of n better th n 3-5 of ar h s l rg ly been repla ed by other in truments n magn t c ol servatories and for first q al ty m gn tic fi ld w rk (s e EARTH INDUCTOR) [J H NE]

B bli graphy See MAGNETOMETER

Inclusion blennorrhea

An inflammat on of th o juncti a of tl new b rn s eye cau ed by a irus of l rge p rticle size ident al in mo ph l gy w th the tr homa i us The nfect o s u its of th n nb cterial on junct it s are lementary bod e wh ch f rm cyto- pla m c n l ons in the conjun ti al cell The d fferenti ti n of th s d e s from tr choma rest th d m l rity f th linical p tures only t a h ma g es r t carr ng of th l ds and pa n s

So-c lled wimm ng pool c nju cti iti s of the ame et ology a njunct it s of th ewborn Si ce the res rv r eem t be the ge ital tract wat r f wimming p l i sa d t be infe ted by di ch rg s fr m the ge ital tract of infected bath r Chlori ation f water elim nate th s urce f d It o j cti t I fecti n of the newborn s eyes c mes f m the ge ital t ct f the mother

Sulf n m de g en by mouth re eff tive ag n t w mm ng pool c ju cti ti top cally appl ed s lfad az ne i tment s ccessf l n t at m t and pre e ti n in nfant Se VIRUS [K F ME]

Inclusion bodies (virus)

Abnormal tru t re which appear w thin th cell n cle th yt pla m or both d r ng the o ir of u mult pl ati n Th y u lly ha e ch a ter i ti tai i g p op rt e In gen al th inclu n l d e con erned with the d vel pm ntal proc e of the i u In me v r i fe t s such a mollu um ntagi m in l ion bod may be mply m s f matu i g virus part cles I th f t s (h pes impl) typ l n lu on bod d n t appe r until aft r the iru h m lt pl ed a d the e n l ion m y b e n ant of th pr s of s m ltiplic t n S HERPES IM LEX

Th prese e f i lu on bod is often im p rta t in d g A cytoplasmic i clu ion n rv cell the N gri body p thog om fo r b es S RABIES VIRUS [J L M]

Incompressible flow

Fl id m t o w tho t h ng n den ty F p a t l pu pose l qu d as med t fl w inc m p es bly At l w eloc ty th s ne rly the a h e e fo l qu d ab upt ch ng s in loc ty prod ce mpr i n r r f ti n (WATER HA I IER) U ll liq d flo u d th tion of gra ty t cc py th l w r port f an op n

l Th p p ty s t k n as th d tingu hi g f tu f a l q d A g s, i tr t flow com

pre sibly to occupy any clo ed pace to which it i confined regardle s of the initial volume of gas and pace Thi property di tingui hes a gas As with liquid low flow of a gas is clo ely approxi mated by a uming it to be incompre ible For example at airplane peeds below about 200 mph the flow of air about a body can be analyzed as in compre ible Usually the dividing line is taken a a Mach number of approximately 0 3 Below this velo ity flow is con idered incompre ible In thi region the Reynolds number provi le a mea ure of flow characteristic The approximation brings everal implifications Den ity and temperature are a umed to be con tant during incompre ible flow Like frictionle s mechanical motion incom pre ible flow is a u eful engineering concept but not an accurate description of reality *See* AERODY NAMIC FORCE COMPRESSIBLE FLOW FLUID FLOW PROPERTIES MACH NUMBER REYNOLDS NUMBER

[J F MA]

Indene

A colorle liquid hydrocarbon (al o called ben z cyclopentadiene) which boils at 181 C and freezes at −2 C It is usually obtained from the light oil fraction (boiling point 178–182 C) pro

CH_2

In lene C_9H_8

duced in the carbonization of coal but it is al o obtained by the pyrolysis of certain petroleum frac ti n

Indene re embl cyclopentadiene in that one hydrogen of the methylene (CH_2) group may be replaced by dium Indene may be oxidized to phthalic acid or reduced t indan (C_9H_{10}) In the pre ence of acid indene polymerize Copolymer with b nzofuran have been manufactured n a small cale for u e in coating and floor covering *S e* POLYNUCLEAR HYDROCARBON [C K B]

Index fossil

Any fo il which identif e and dat the rock trata r ucces i n of trata in which it lie The name f the index f il i u d to de ignate the trata (zone) containing it uch a the Cambrian tril bite zones and Ord vician grapt lit z ne The term guid fo il i applied to any f il that is u ef il f r purp e of identif ation r rrelati n The u efulne of b th guid an l in lex f il d p nd upon th eir re tri ted ve tical (tratigraphi) rang wi le prea l g grap lic li tril uti n abundan and di tinctive characteri ti *See* FOS IL *s e also* STRATIGRAPHIC NOMENCLATURE [N A B]

Indian Ocean

The boundarie of the Indian Ocean ad pted by th I an Indian Sci nce A ociati n in 19 3 includ the Red Sea (ar a 438 000 km²) P r ian G lf (239 000 km²) Andaman Sea (90 550 km) Arafura Sea (1 391 000 km) and Ba Strait (000 km) al o that part of the Southern Ocean be tween 40 S and the Antarctic Circle and extend ing from 20 E in the we t to a line in the ea t al ng the Balleny–Macquarie–Mill Ri e Ridge to S uth Cape in Ta mania (23 301 000 km) The t tal area i 77 918 000 km (1 km = 0 3861 mi) The ocean sector n rth of latitude 50 S i di cu ed be low *See* ANTARCTIC OCEAN

Ocean floor The floor of the Indian Ocean i di vided l ngitudinally by the Carl berg Mid Indian Kerguelen line of ridge (Fig 1) North of the is land of Rodriguez (20 S) the general depth f the ridge sy tem is 2300 2700 m with a lea t depth of 836 m outhward it ri es to the i lan l of New Am terdam St Paul Kerguelen and Heard We t of thi line the marine sediments are chiefly gl big erina ooze ea tward chiefly fine re l clay f terrig enous origin with volcanic depo it pre ent in the Indonesian arc The deepe t ba ins and trenches occur ea t of this line of ridge and include the Wharton Deep 6460 m and the Sunda (Java) Trench 7455 m Little i known of the deep circu lation in the ba in of the Indian Ocean

Temperature and salinity In the oceanic area of the Indian Ocean data are sufficient to h w g n eral sea onal differences in the di tribution of sur face temperatures and alinity but n t h w de tailed a p ts of annual variatic n In c a tal ar a the amount of detailed informati n is much great r but often i not suff cient to h w the di tributi n of temperature and alinity becau e f the greater variations which occur there

Surface t mperatures The mean surface tem perature in February (Fig 2) sh w th e influence of the southern hift of the thermal equat r th of Augu t (Fig 2) sh w the northward shift The i otherms run generally fr m we t t ea t an l are not greatly diverte l by the ean urr nt A in the other ocean the temperature f th de p water decrea e fr m 3 C at ab ut 2000 m t 1 C at th bottom

Surface salinity The Arabian an l Re l Sea are areas of high urface alinity Arab ian Sea surfac water exten l s uthwar l toward Madaga car (Fig 3) In the s uth a belt f high alinity wat r exten l from South Africa t war l thw t A tralia reaching alinity val high r than 3 part p r th ou and (oo) near Au tralia Owing t ri r run off and high rainfall alinit l than 31 oc ur in the Bay f B ng l n l we t f S matr The p r manent exi ten f the ar a f l w alinity h wn south of Java in Fig 3 i 1 t f il

Surface currents S uth f latit l 10 S r fac rent f rm t lockwi ir lati n whi h c ntinu thr ugh ut th ye r In th lati t l of th 40 th we t win l y t m maint in an ea twar l drift f urf e wat r Part f th *drift continu a twar l t th f A tral t th* m in rrent i f fl ted n rth t f rm th maj r part f th S uth E q at rial Curr t whi h et rn toward th Afri an C a t Th r it bec m th Ag lha r m whi h fl ws s uthwar l betwe n

Fg 1 Phy g ph f t f th I d O floo (Aft R F b dg)

Fig 2 M f t mp t (C) F b ry d A g

Fg 3 S l ty rth rn mm (Aft H U S d p)

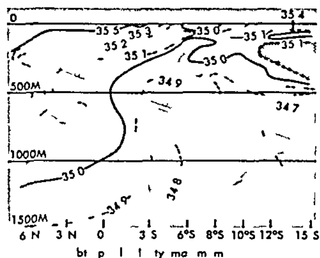


Fig 4 Relations of water masses in the upper 1500 m of the Indian Ocean from 6 N to 15 S along 50 E based on records of salinity obtained in 1935 by the French vessel *Norsel* (*After Tchernia Lacombe and Guibout 1958*)

Madagascar and Africa In the southern winter the South Equatorial Current also contains water entering north of Australia from the Pacific Ocean In the southern summer this contribution ceases *See* SOUTHEAST ASIAN WATERS

North of latitude 10 S the circulation is determined seasonally by the prevailing winds In February and March when the northwest monsoon prevails the North Equatorial Current (east to west) is well developed and an Equatorial Counter Current (west to east) is present between 2 S and 4 S between the Gulf of Aden and 5 S a current flows to the south In August and September under the influence of the southwest monsoon the North Equatorial Current disappears and is replaced by the Monsoon Current (west to east) The Equatorial Counter Current forms part of the general eastward surface flow in the northern Indian Ocean during this season and a stream (the Somali Current) runs northward along the African Coast from 10 S to 10 N

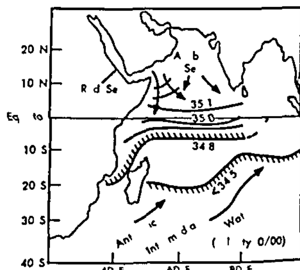


Fig 6 Southern limit of Red Sea and Arabian Sea water and northern limit of Antarctic Intermediate Water at 1000 m (*Adapted from J LeFloch 1951*)

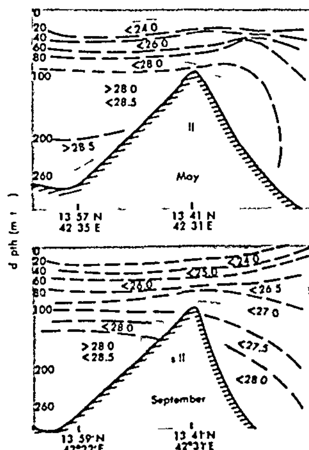


Fig 5 Distribution of density (σ) and direction of current at sill of Red Sea in May and September (*After E F Thompson 1939*)

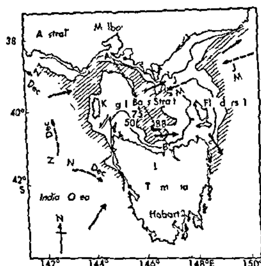
Subsurface circulation Little is known about the subsurface circulation north of 50 S because ocean station data for depths greater than 1000 m are sparse From the available data however and from data obtained in the upper layer it is possible to show the interactions of the more important water masses namely that originating in the Red Sea Arabian Sea area and that originating as Antarctic Intermediate Water (Fig 1)

A high rate of evaporation in the Red Sea (length 1000 mi width 150 mi maximum depth 2800 m) leads to the formation of relatively dense bottom and intermediate water (temp <2 C salinity >37‰ density σ > 7 0) This water flows into the Indian Ocean over the sill or ridge near the entrance of the Red Sea (Fig 5) The flow is irregular and greater in the northern winter than in the summer This water along with that formed in the Arabian Sea spreads easterly toward longitude 80 E and southerly toward latitude 10 S at intermediate depths (1000 3000 m) mixing with surrounding ... water in its passage (Fig 6)

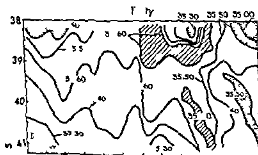
Antarctic Intermediate Water (salinity 33 8 ‰ temp 2 2 C) formed at the Antarctic Convergence flows northward in the Indian Ocean In the western area it moves ... from 1000 ... 0 S to 300 m at 8 N and loses its identity ...

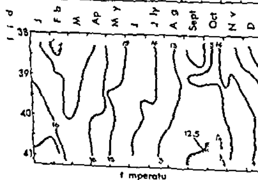
80 F a d 100 E t c nt nues at about 1000 m t 12 S d then ri es sharply t ward the surface (F g 6) [K..]

Bass Strait Th Ba s Str it li between the Au tr l an mainland a d th isla d f Ta man a It i imp rta t way c nn ctin ea tern and west er A t al n port nd the ce ter f th p inc p l b rrac d and school shark fisl er e of Au tra l It b an pp oximate are 145 000 q mi, with



Fg 7 Ch rt f B St t h w g p l g t d d t d m th f t ory sets. D t f m A t l Pl t d d ft b ttle l (C.S.I.R.O D F h O ea g C ll A st l)





mo im m m m m

Fg 8 Sal ity d t mp t e ch g of g th h A B l F g 7 d g 1957 (D t f m C.S.I.R.O Div F sh O ea og C ll A st l)

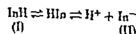
an verage d pth of 60 m *There s a deep cl annel* (75–80 m) through the e tral and northwest ec tions (F g. 7) D ring the w nter and early pring a g neral mo em nt of Southern Ocean water nt Ba s St a t ccur through the western appr ache By No emb to December howe e c ntrary ts e pecially b tween Kin I I nd a d th Vi t r an mainland all w the ingre s f om the ea t of sub-tr p al wate s fr m outhern New South Wale and e te n T m n a To m ext nt the e ha g i i cul t on d termine the ea onal a l ty temperature ch ng s (Fig 8) Dur ng Apr l to Ju Ba Str t water ha e tl alin ty (35 40–35 50 ‰) and temperatu e (14–16 C) typical of South rn Ocean wat r we t of Ta man a at th t time Fr m July to O t ber the h he t ali ity waters (= 35 60) flow i to B ss Strait from South Au tralia Low sal n ty wate (3. 00–35 30 ‰) oc ur du ing the spring and summer along the V ct r an coa t b t in general their effect o Bas St ait i l ght The d scharge of large quant t es of water reta ned u t l early ummer as ow d ic i the m ntain reg ns f the major T sm n an ri e f rms a la ge b *dy of Ta m n an* coa tal wate wh ch ha a ma ked effect o alin ty v l es in the Bass Str t d ring Decembe nd J nu ry S e PACIFIC OCEAN [D J R]

Bibliog aphy J N Jenn ng Th submarine topography f Bass Strait *P c R y Soc (V c tor a)* n 1 71 *pt* 1 1959 M J P llak Frequency di tr b ti n of p tent al temper t re nd l t n the Indi n O ean *D p-S a R ea ch* 5 128–133 1958 G Schott *G g ph d s I dis h u d Still O* s 193

Indicator acid base

A ubstan that rev l th ough characte i t c c l ha g tl deg e of idity r b si ity f l t o s Indicat r a e we k org ac ds or ba es wh ch x t in mo than o e truct ral form (*tautom*) f wh h at lea t one form i olored Inten e ol de ble that y l ttl d at s need d th i d c t r it elf w ll thus not ffe t th acid ty of the lution

Th equ l b m r a t n of d cator may b reg ded typ ally by gi ng t th f *rmula* HIn It d iate t H nd In ions a d n equilib-um w th taut m r I H whi h i e the a n n ele t I t or at m t i n zes ery l ghtly In th o ll equ l l i m



$$\mathrm{InH} \rightleftharpoons \mathrm{HIn} \rightleftharpoons \mathrm{H^+} + \mathrm{In^-}$$
$$\text{(I)} \qquad\qquad \text{(II)}$$

th mpl fy g as umpt on th t the i d c t r e t nly in form (I) and (II) leads t no d ffi ulty The add t n f c d w ll c mpletely c n ert th ind cato t f *rm* (I) whi h the ef r alled th c d f m of the i d at lth ugh t s fun i n g a a ba A hyd o d b e co verts the d t to f rm (II) w th the f rmati n of water th is alled the alk l f rm For th equ l b-t um between (I) nd (II) the q l b m n ta t s

$$K_I = \frac{[H^+][In^-]}{[InH]}$$

In a manner similar to the pH designation of acid ity that is pH = −log [H] the K_I is converted to pK_I with the following result

$$pK_I = pH - \log \frac{[In^-]}{[InH]}$$

It is seen that the pK of an indicator has a numeri cal value approximately equal to that of a specific pH level

Use of indicators Acid ba e indicators are com monly employed to mark the end point of an acid ba e titration or to measure the existing pH of a solution For titration the indicator must be o chosen that its pK is approximately equal to the pH of the system at its equivalence point For pH measurement the indicator is added to the so lution and al o to everal buffer The pH of the solution is equal to the pH of that buffer whi h gives a color match Care mu t be u ed to compare colors only within the indicator range A color comparator may al o be u ed employing tandard color filters instead of buffer olution

Indicator range This i the pH interval of col r change of the indicator In thi range there i com petition between indicator and added ba e for the available protons and the color change f r exam ple yellow to red is gradual rather than in tanta neous Ob ervers may therefore differ in electing the precise point of change If one a ume arbi trarily that the indicator is in one color form when at least 90% of it is in that form there will be un certain color in the range of 90% to 10% InH (that is 10% to 90% In) Upon ub tituting these arbitrary limits into the pK equation it is een that the interval between definite color i from

Common indicators

Common name	pH range	Color change (acid to base)	pK	Chem cal name	Structure (acid or base)	Solution
Methyl violet	0 - 5 6	Yellow to blue violet to violet		Pentamethylbenzyl par ros nil e hydro- chloride	Ba	0 - % in wat r
Metacresol purple	1 8 7 3 9 0	Red to yel low to pu ple	1 5	*m* Cr sol ulfon phth lein	Acid	0 3% in N/ 0 N OH dilute to 0 01%
Thymol blu	1 - 2 8 8 0 9 6	Red to yel low to blue	1	Thymol ulfon phthal i	Acid	0 93% in N/ 0 NaOH d lute t 0 01 %
Tropeoline 00 (Orange IV)	1 4 3 0	R d to yel low		Sodium *p*-d pl enyl am inoaz benzene- sulfon te	Ba	0 1% in water
Bromphenol blue	3 0-4 6	Yellow to blue	4 1	Tetrabromophenol sulfonphth lein	Acid	1 39% in N/ 0 NaOH dilute to 0 01%
Methyl orange	- 8-4 0	Orange to yell w	3 4	Sodium *p*-dimethyl am inoazobenzene- s lfonate	Base	0 1% in water
Bromcresol green	3 8 5 4	Yellow to blue	4 9	Tetrabro o-*m*-cresol ulfonphthalein	Acid	0 1% i 0% alc l l
Methyl red	4 6 3	Red to yel low	5 0	Dim thyl minoazo- benz ne-*o*-carb xylic acid	Base	0 5 i N/ 0 NaOH dil te t 0 01 %
Chlo phen l red	5 0 6 8	Yellow to red	6 -	Dichl rop en ls lfon phth lein	Acid	0 8 % in N/ 0 NaOH dil ite to 0 01%
Bro cresol p rpl	- 6 8	Yellow to pu pl	6 4	D brom o-cresol ulf n ph th l in	Acid	1 08% in N/ 0 NaOH d l t t 0 01
Br m th ymol blue	6 0 6	Yell w to blue	3	D br thy l ulf ph th l n	Acid	1 i N/ 0 NaOH l t t 0 01
Ph n ol red	6 8 8 4	Yellow t red	8 0	Ph ol ulf nphthal in	Acid	0 71% N/ 0 NaOH l ite t 0 01%
Cresol red	- 0 3 0 ? 8 8	Orange to amber t red	8 3	*o*-Cresol lfonph th l n	Acid	0 % i N/ 0 N OH d lut t 0 01
Orth res l phth l n	8 - 9 8	Col les t red			Acid	0 01 i l l l
Ph n lphth l n	8 4 10 0	Colorless to pink	9		Acid	1% i 0 l l l
Thym lphth l n	10 0 11 0	Colorles t red	9 9		Acid	0 1 i l l l
Aliz i y ll w GG	10 0 1 0	Yell w to l l		S l p- tr benz ne a o l yl t	Acid	0 1% i w r w t r
M l h it green	11 4 13 0	Green to lo les		*p p* B n yl len l - N N-d ethyl l ne	Base	0 1 i w t r

$$pH = pK + l \frac{10}{90} \quad t \quad pH = pK + l \frac{90}{10}$$

Thu the pH certa nty of the ı d cator s from pK + 1 t pK − 1 (approx mat ly) a d pK ± 1 s c lled th range f the nd t r Th e p r m n tally b rved ange m y d ffer f om tl s p edı t n m wh t b a f a ı t n c lor n t n ty

Examples The a company ng tabl l sts ma y of the c mmo d cat r the r chem l names pK v l e r ges f pH nd d r ct ns f r m k g l t o Ma y f the weak a ıd d ato s a e fir t d sol ed ı N/50 NaOH to the c nc nt atı n h wn then f rth r d luted with water The weak b se ı dı at s sh w ome temp r t r ariatı n f pH rang foll w ng app x mately th t mp ra t re ha g f the o zat n n t nt f w t r W k a d d at a e m r tabl toward tem pe at ch nge The colo s a e f rmed by tl u al ch om ph r c g up for e ample qu n d nd azo O e of the m t comm n nd c t s ph n lphthale n bta ned by o d ng phthal c nhyd de w th phen l The a d form s ol rless It c ert d by OH o t th red q n d f rm

Othe ı d t r u h s m thyl o a ge a d m thyl red are sod um s lts f azob nz ne d rı t es on t ı ı g ulf n nd a b xyl groups e pec t ely S e ACID AND BASE HYDROGEN ION TITRATION

[A L H]

Indium

Chem l l m t numbe 49 ndı m In h s at m w ght 114 8 d ı memb f gr p III nd th fifth pe ı d f the p d t ble It v l n e fig rat $5s\,5p$ wh h It ı ma m m x d t o t t f III Comp ds f th x d t n t ı l nd app nt ox l t st te II l reported Th Gold hm dt d u f) th In ı 0 81 A

I d um occ r ın the arth ru t to the te t f about $1 \times 10^{-}$ % It ı w d ly d t buted ın s m y a 50 m l d o es, p rt ul ly tho e f n wh h ıt may mo t to 0 1%

Th tu l ses of nd m f w a r flected by a t t l d mest produ t l 87 600 (t oy) ı 1956 Th l m nt ı ed ın sleeve be r g ı l k nd ın g ld dental all y l d um ca be u ed d t n f m nd t I d m pho ph de h s u ın high temperature transistors and solar bat te ı ndium a enıde and ınd um antım n de are u d l w temperature transı tors

Indium metal Indı m ıs eco e d f m a by p odu t of th zınc s lfide smeltı g proce s An a d l ch ıs f ll wed by h mı al sepa at ons from multıt de of oth r elements su h as zınc cadmı m ır n ar n c ant m ny nd al ımınum Th f n l p r fic tıo t 99 9% p rıty ıs u ually ac ompl hed by queous lectr lys Ind um ıs a ft m tal wh ch an be e sily c atcl ed with the fi e na l It ha the ınte est ng prop rty of adher ng t the s rfaces wh n rubbed a r s them It ha a melt ng point f 156 4 C, a l oılıng poı t g eater tl a 2000 C and a den ıty of 7 31 g/cm at 20 C. It cry t llız ı th f e-c ntered tetrag n l truct re The stand rd oxıd t on pot ntıal fo the act n

$$I \rightarrow In + 3$$

ıs +0 34 v lt The met l dı l es n all cıds t g e solutı n f tl ıdat on tate III The t of xıd t n of ınd um metal by oxygen f the a r ı ery low up to the meltıng po nt b t at hıgh temperatu es t rap dly y ld the vell w x de I O I dı m r a t d ectly w th the h l gens when w m

Indium compounds Ele t d ff a t on studies sh w th t the hl rıde br mıde nd ıod de a e all dım rıc the p r st t The anhyd u fluorıde nly ry sl ghtly s lubl n water whe e s the the t hal d r ery oluble Although the t ı ıod d s p l y ll w ın olo the th r tr hal d are col rle s The trıhalıde hyd ates ar r c v red f m the aqueou ol tıon

In q eo s lutı n th o ly stable oxidatıo state of nd m ı III A 0 1 M l t on of ınd um t ıhal des hyd ly s t g e a pH of abo t 3 Upo the dd tı n of b e ı u h a ol tı n th h drated xıd p p tate at pH of about 3 4 Indıum hyd o de s not amph t r d e the t ale t o fo m a st ble compl x w th mmonı The car bon t o l t d s lfide n ol ble wat

Comp u ds f th mpo t InX e pt f the d d h e bee p ep ed The fluorıd p e p ed by pa t l ed ct f the t fl o de w th hydr ge a d th hl d nd br m de by a t f hyd g n hydroge h l d g m t r on the c rrespond g t h l de Th hlo ıde nd b om d

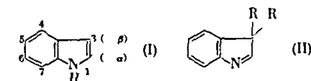
both melt at 235 C The e compound are diamagnetic and thus may be $In^{I}(In^{III}X_4)$ compounds Reduction of the trichloride and bromide with indium metal re ult in product of compo ition InX When added to water the reduced tate compounds di proportionate to the metal and the oxidation state III

Indium forms organometallic compound mainly of the R_3In cla s where R is either alkyl or aryl The reaction of indium metal with mercury alkyls (aryls) give the de ired products Indium organometallic compound tend to be a ociated in olution and are easily oxidized in the air

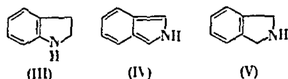
Indium may be determined quantitatively with 8 hydroxyquinoline by precipitation of the compound $In(C\ H\ ON)_3$ at 70–80 C from a odium acetate–acetic acid buffer followed by drying at 120 C and direct weighing of the precipitate An alternate to the direct weighing i the bromometric titration procedure after solution of the compound *in warm 10–15% hydrochloric acid or the c l ri*metric determination at 400 mμ of a chloroform olution of the 8 hydroxyquinolate *See* GALLIUM THALLIUM [F M L]

Indole

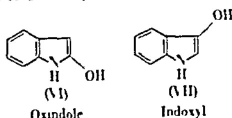
One of a group of organic heterocyclic compounds in which a benzene ring is fused to a pyrrole ring Indole (I) is a typical member of the group (*see*

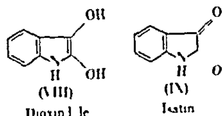


HETEROCYCLIC COMPOUNDS PYRROLE) Indolenines refer to i omeric y tems which are of intere t g nerally only wl en two gr ups are pre ent at the 3 po ition a in (II) *2 3 Dihydroindole i called* indoline (III) The dihydr i ind le system (V)

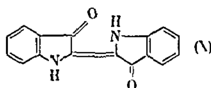


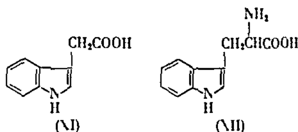
ha recei ed me tudy th i oindole sy tem (IV) much le Ind le ul tituted with oxygen at p i ti n 2 or 3 have pecial names (VI–IX)





The indole keleton occur in many natural product Example might include the blue dye indigo (X) the plant growth hormone heteroauxin (XI) the amino acid tryptophan (XII) and the indole alkaloid for example trychnine Trypto-

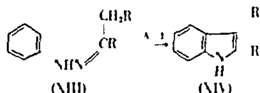




phan not only is one of the e ential amino acid for man but al o i the biochemical precur r of the indole plant alkaloid it i al o very likely the progenitor of indole and 3 methylindole (katole) which are produced by pyroly is or putrefacti n of protein material

Properties and preparation Indol (I) is a team volatile colorle olid mp 52 5 bp 253 C It is found in mall amount in coal tar in fece and in flower oil Indole i not ordinarily cla ed as acidic or ba ic although it i an active hydrogen compound in which hydrogen at the 1 p iti n i replaceable by metal In the ab ence of oxygen ind le i tal le to heat and to alkali Indole are en itive t acids and to oxidati n proce e h w e er the more highly ul tituted ind le are in general m re tal le Ind le can be regarded a relatively reactive ar matic compound Electrophilic ul tituti n favor the 3 p iti n and t a l er extent the 2 po iti n The exp rim ntal resonance energy for ind le is 54 kcal m le

Ind le ynthe e pr e l l y fu ing a fi e membered N heterocycle on a b nzenoid compound Of the many known synthe e the Fi cher ind le synthesi i the mo t versatile By thi method a ph n ylhy lraz ne (XIII) of an aldehyde or ketone on treatm nt with a i l i n erte l t an ind le



(XIV) F r xamp l wl n th tarting mat rial i *the phenylhy lrazi ne of ac t n th p r luct i* 2 methyl n l l Th R gr u at in l l p ti n and 3 may be vari l wi l ly S l titut l i l l ar f rmed when th p l nylhy lraz n (XIII) i ul t tuted n th l enz n ring An th r ynth i cyclic o t lui f d ri ati (XV) t in l l (XVI) l y l ting th m in th p f tr gly l a i re g nts

(XV) (XVI)

I d l s r atta ked at the 2 3 b nd by r z ne per x des and ther reag ts Catalyt hy d gen t y eld n t nly indoli (III) but l d pe d ng o c dit n octahyd oi dole (XVII) nd o ethylcy l l xylam n (XVIII)

(XVII) (XVIII)

I dol ub t tut t the 3 p t n ometime t the 2 p u n but only ra ely th ben n g Gr p i serted by ub t tut on n l de chl o odo n t o n tr l az Ind le 3-car bo ald hydes e f rmed n th re ct with hl f m nd lk l (R mer Tiema n) r with N methylf rm n l d a d ph ph s ychl de Th I sod de t of dol re t with methyl od de to gi e m nly l m thylind le I d les with ethylmagnesi m od I gi e l nd l l m gnes m od d wl t c mb with lkyl h lid yl h l d b di x de ethyl chl o- bo t f rm ld hyde and ethyl o th form t t g expect ly 3- lkyl ndoles 3- cyl nd l d l 3-ca bo yl ac d the corre po di e t 3-hyd ymethyl nd l nd dole 3- box ld hyd s.

Important derivatives Gramine r 3-d methyl ami omethyli dole (XIX) i one f the impl e t nd le alkal d G amin i prep red by condensa t of indole d methylamine and fo maldehyde The dimethylam no grouping either a such or aft r qu tern zat on an be d pla ed moothly by nu le philic gr up Thi property has been ex ploit d fo the sy thes s f va i u 3- ub tituted i d le For exampl the re cti n f gramine with od um cy nide g es 3-cya omethyl nd le (XX) wh ch is hyd olyzed by alk l t gi e het roau i (XXI) r whicl redu ed by hyd ogen and Ran y nickel c taly t to trypt mine (XXII) Gra mi e w th ac t m d mal nic este give the inter mediate (XXIII) wh ch can be converted to tryp- tophan (XXIV)

S r t in or 5-hyd ytryptami e (XXV) an ff cti e lo al vas co tr ct is d stributed th ugh ut the body Buf teni e (XXVI) fo nd in the sk n of tl commo t ad i a act e pre r g nt Both ser t in nd bufote i e ha e been ynthe ed 5 6-D hydroxy nd le derived in vivo l y the biochem cal o id t on a d d carboxyl tion of tyros ne gi s ri e by furthe x dat on to the da k k n pigme t mel n Th ind l e e e ne r phy tigm e (XXVII) s a pecific nhib tor t th act n of ac tyl l l e t ra nd a u h is eff cti n block g erv cond ct on Gl tox n (XXVIII) a f ngus der ed antib t

Ind g dye h s be n k wn for e tu ie Ind o r d oti (XXXI) a d its der ati es in lud g the thi nd g in wh h S tak s the place of NH are mme c ally mp tant dyes I d ca (XXIX) a glu os de of indoxyl is f und in ar u pec e *f I d g f ra* Natu al nd go i ob- ta ned by zym t c hyd olysis f nd an f ll wed by ai ox dat n of the es lt ng ind xyl (XXX) *Although* ma y synthe es ar known th impor t t c mmer i l ynthe e a losely related t th t how in the a c mp nyi g form lat ns in

(CH) NH / CH₂O → (XIX) → NaCN → (XX) → KOH → (XXI); (XX) → H → (XXII)

(XXIII) → (XXIV)

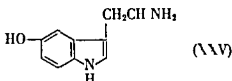
which phenylglycine (XXXII) is an intermediate Substituted indigos are prepared from indigo or by total synthesi The bromo and chloro derivatives are valuable dyes Tyrian purple or 6 6 dibromo indigo i a dye of antiquity obtained from a Medi terranean snail

3-Hydroxyindole or indoxyl is a yellow com pound with an unpleasant odor It is ea ily oxi dized with air or with ferric chloride to indigo Reduction with odium amalgam or with hot zinc du t affords indole The reactive 2 position of in doxyl combines readily with aldehydes to give col ored indogenide such as (XXXIV) and with nitrous acid to give isatin α monooxime (XXXIII)

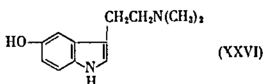
Oxindole is 2 hydroxindole however the tau tomeric amide structure (XXXVI) is probably the more appropriate formulation Oxindole can be prepared by Friedel Crafts cyclization of N (chloroacetyl)aniline (XXXV) or by a two-stage re duction of isatin The oxindole 3 po ition may be alkylated nitrosated acylated or conden ed with aldehydes

Dioxindole (XXXVII) is produced by hydro ul fite reduction of isatin (XL) or by cyclization of *o* aminomandelic acid (XXXVIII) Oxidation of dioxindole regenerates isatin reduction gives oxindole (XXXVI)

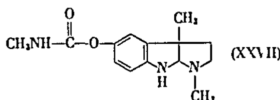
Isatin or 2 3 dioxoindoline (XL) is prepared by oxidation of oxindole by oxidati e cleavage of in digo or by ring synthe is One standard i atin syn thesis (Sandmeyer) proceeds by cyclization of isonitrosoacetanilide (XXXIX) which is obtained from aniline and chloral oxime I atin is a red weakly acidic material The reactive carbonyl group at the 3 po ition takes part in familiar car



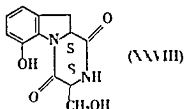
(XXV)



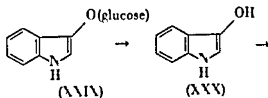
(XXVI)



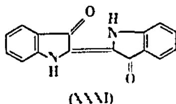
(XXVII)



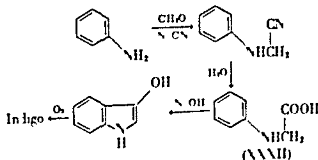
(XXVIII)



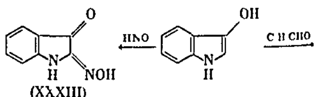
(XXIX) (XXX)



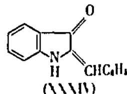
(XXXI)



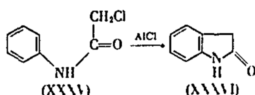
(XXXII)



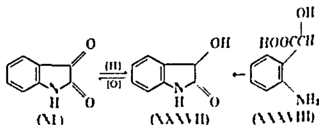
(XXXIII)



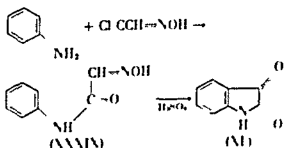
(XXXIV)



(XXXV) (XXXVI)

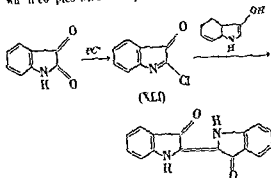


(XL) (XXXVII) (XXXVIII)



(XXXIX) (XL)

bo yl dd t n reacti s Ph ph u p ntachlo-ride c nverts ati to i atin α bl r de (XLI) wh h co ples with ndoxyl in a tandard and u



t I i d g ynthes I atin an be c n ert d the Pfit ge p o es t quinol e deri ati e S e QUI OLINE [W J CE.]

B bl og aphy R C. Elderfield (ed) *H t cy l c Comp ds* v l 3 1952 W C. Sumpt d F M M lle *Het rocyclic C mp ds u th Ind l and C ba ole Sy tem* 1954

Inductance

That pr pe ty of an electr c ir it r of two neigh bori g i u t whereby n el ctr m t ve f c d c d (by th proce f el ctrom gnet c ndu t n) of the i u ts by a cha ge f curr nt i th f them S e FLECTROMOTIVE FORCE (EMF) INDUCTION ELECTRO I C FTIC Th te m i d t n I s metim ed a a syn nym f r du t a d p e g the p operty of d t (e INDUCTOR)

Self inductance F r g e oil the rat o of th lectr m ti fo ce of i d ct o t the rat of ha ge f rr t the o l i call d the elf ndu t L i the l

$$L = -\frac{e}{dI/dt}$$

wh e th l t m ti f e t y n t nt d dI dt th r te of ha g f the urre t t th t t nt The n g t ign di te that the d ed I ct om i f t opp it i d c t i th e nt h th t n rea ing (dI dt po t e) a d th same d ect o as th t wh the u e t i d c e g (dI dt n gat e) The s lf ndu t n t h tys wh th l t m ti f c n olt d it t f h ng f r t n amp es pe sec nd S HENRY

A aft at d fi t f elf nd t n s th mber f fl x l k ges p r unit nt Fl x l nk g th p od t f th fl x a d the umb r f tu n th l Th

$$L = \frac{N\Phi}{I}$$

M lt pl both des f th q at o by I t bt i

$$LI = N\Phi$$

and d fferentiate with r spe t to t

$$L\frac{dI}{dt} = N\frac{d\Phi}{dt} = -e$$

or

$$L = -\frac{e}{dI/dt}$$

Henc th ec nd definitio eq alent t th first

S lf ind ctan e do s not affe t a c r uit in which the curr nt i un ha ging but it i f gr at impor tan e wh ther s a ch nging current inc there i an indu ed emf du ing the tim that the change takes pla e F r xample in n alternating u r nt ci cuit th urr nt s c n t ntly hanging a d the nductance is an important fact r Al in tran si t ph n m n at the beg nning or end f a teady unid r ctio al current th elf nductance plays part *See* TRANSIENT ELECTRIC.

Con id r a ir it of res tan e R and inductance L onnected in ser e to a on tant urce of po-tent al diff en I The cur ent in the c rcuit d s not rea h a fi al teady al e in tantly but ri es t wa d the final alue $I = V/R$ in a man e that d p nd pon R a d L At e ery in t nt after th wit h s clo ed th applied pot nt al diffe ence th sum of th iR d p i p tential and the ba k mf $L\,di/dt$ o

$$V = iR + L\frac{di}{dt}$$

whe e is th in tant eous value of the c rre t Sep r t ng the i ble i nd t o e obta ns

$$\frac{di}{\frac{V}{R} - i} = \frac{R}{L}dt$$

Th olut on of this q at on

$$i = \frac{V}{R}(1 - e^{-(R/L)t})$$

The curr nt r es e p nt ally t fi al te dy lu V/R The rate f gr wth ap d at fi st the le s a d le s p d a th urrent appr ches the fi l al e

The p we uppl ed t th circ t at ve y in ta t duri g the r f curr nt is gi en by

$$p = iV = i^2R + Li\,di/dt$$

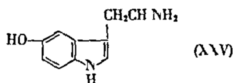
Th fi st term i^2R is th p er th t goes into he t ing the c t The e nd term $Li\,di/dt$ s the powe th t g es t b ild g up th m gn t field in th nduct The total e gy th t ed n b ld g p th magnet c fi ld i

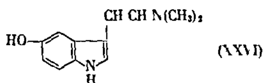
$$W = \int_0 p\,dt = \int_0 Li\frac{di}{dt}dt = \int_0^I Li\,di = \tfrac{1}{2}LI^2$$

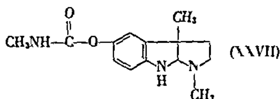
Th ene gy th t h bee d in bu ld ng up the magn t fi ld rema as e e gy f the m g etic field Wh n the tch i op n d th mag et fi ld ll p es a d th nergy of th field s returned t th ci cuit, re lt ng n an ind c d emf The arc

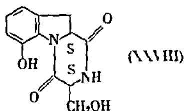
which phenylglycine (XXXII) is an intermediate Sub tituted indigos are prepared from indigo or by total ynthesis The bromo and chloro derivatives are valuable dyes Tyrian purple or 6 6-dibromo-indigo i a dye of antiquity obtained from a Medi terranean snail

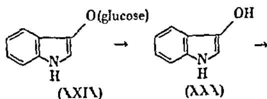
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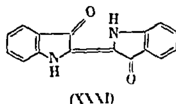


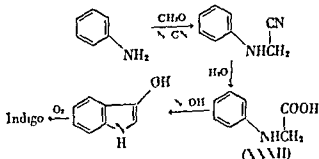










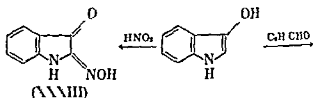


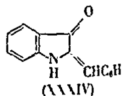
ored indogenides such as (XXXIV) and with nitrous acid to give isatin α monooxime (XXXIII)

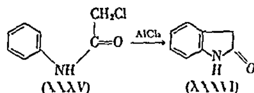
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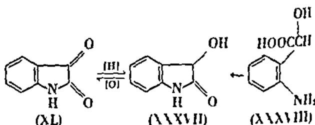
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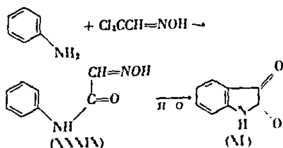
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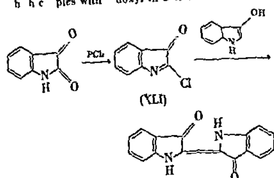








bonyl addu react n Pho ph r pentachlo- de con erts at n to sat -α-chl ride (XLI) b h c ples with doxyl in a st nda d and e-



ful ind g ynth i I atin be con rted n the Pfitz ger process t qu n l n de v t e *Se* QUINOLINE [W J GL.]

B bl g aphy R C. Elderfi ld (ed) *Hete ocy l c Compou ds* l 3 1952 W C Sumpt r and F M M lle *H te ocy li C mp d with I dole nd C b l Syst ms* 1954

Inductance

That p ope ty of an el ct c r u t f tw neigh bo g c r t wh reby a el t omoti fo e i i d ed (by th p es of electromagn ti i duc t n) n of the ci u t by a h nge f current i th of th m S ELECTROMOTIVE FORCE (EMF) I DUCTION L CT O IA ETI The term ind cta c e il s m tim us d a ynonym f d t a de ie po i g th pr p rty f du t (INDUCTOR)

Self inductance Fo a g en co l th r t f th l tr m t e f e f i duct on t th ate f ha g of rr t i tl l all d th s lf d t n *L* of th e L

$$L = -\frac{e}{dI/dt}$$

h th lect mot e l c t any in t nt nd *dI dt* th rat of cha g f the rrent at *th t* t t Th n g ti gn i d cates th t th ndu ed lectr m t for e opp te n di ec t n t th nt when the c r ent c a ng (*dI dt* po t ve) and n th s m d ect n the *nt* h n th u t s d re ng (*dI/dt* g ti) Th lf ndu t i henry wh n th lect m t f c lt d the at f h g f urr t amperes per se d S He R

A lt t d fi t o f lf d cta c i th mbe f fl x l k ges per u t re t Fl x l k g th p od t of the fl and th n mber f t n th l Th n

$$L = \frac{N\Phi}{I}$$

Mult pl b th d (th q t n by I to btai

$$LI = N\Phi$$

and diffe ent at with r pe t to t

$$L\frac{dI}{dt} = N\frac{d\Phi}{dt} = -e$$

r

$$I = -\frac{}{dI/dt}$$

Hen e the c d d fin t n i equi alent t the fi t

Self d ctance doe not affe t a c r it in wh ch the urre t i n h n ing but it i of great mpo t n e when the e t a changing current s n e there is an nd ced emf d r ng th time that the change t kes pl ce F r example in an alternati g c i rent c rc it the urrent i c nsta tly hang ng and the i duct n i an mport nt f cto Al n tran s e t phen m n at the beg nning r end f a t ady u d e tional cu rent th elf ndu tan e pl y a part. *S e* TRANSIE T ELECTRIC

Co s der a c c t of e ta ce *R* and inductan e *L* onn cte l in se ies to a con ta t ou ce of po- tential diff re e *V* The c r ent in the c rcuit d e n t e ch a final teady alue i tantly but ri es toward the fi l alue $I = V/R$ i a manne that depe ds upon R a d L At ry in ta t afte the switch is cl ed th appl ed pot tial d ffer nce is th um f the *iR* drop in pote t l and the back emf *L di/dt* or

$$V = R + L\frac{d}{dt}$$

wh re i s the stanta ecu alue of the cu rent. Separ ti g the v iable i and t one obtai s

$$\frac{d}{\frac{V}{R} - i} \quad \frac{R}{L}dt$$

Th ol ti n of this q ation

$$i = \frac{V}{R}(1 - \quad ^{-(R/L)t})$$

Th c rent r es exp nentially t a fin l teady alue *V/R* The rate f g wth i apid at fir t then le and l s p d the rrent appro he the fin l l e

The powe uppl d to the ci c t at ev y n t nt du i g th r e fc r e t gi en by

$$p = iV = \quad R + I \quad d\ /dt$$

The first t rm ^2R is the p we that g t I eat g the c *t The e nd term L d /dt* is th powe th t g s to b ild g up the m gnet c fi ld i the *nducto* Th total n rgy that i u ed i b ildi g p th magnetic field s

$$W = \int_0 p\,dt = \int_0 Li\frac{d}{dt}dt = \int^I Li\,d = \tfrac{1}{2}LI^2$$

Th s ne gy th t ha been u ed i b ild ng p the m gn t c fi ld r ma s a ene gy of the m gnet c fi ld Wh n the sw tch op d the m g et c field ollap es d th *nergy of th fi ld* i ret ned to the cu t. re h ng n an indu ed *emf* The a

that is often seen when a switch is opened is a re sult of this emf and the energy to maintain the arc *is supplied by the decrea ing magnetic field*

Mutual inductance The mutual inductance M of two neighboring circuits A and B is defined as the ratio of the emf induced in one circuit to the rate of change of current in the other circuit

$$M = -\frac{\mathcal{E}_B}{(dI/dt)_A}$$

The mks unit of mutual inductance is the henry the same as the unit of self inductance The same value i obtained for a pair of coils regardless of which coil is taken as the starting point

The mutual inductance of two circuits may also be expressed as the ratio of the flux linkages pro duced in circuit B by the current in circuit A to the current in circuit A If Φ_{BA} is the flux thread ing B as a result of the current in circuit A

$$\mathcal{E}_B = -N_B \frac{d\Phi_{BA}}{dt} = -M \frac{dI_A}{dt}$$

or

$$N_B \, d\Phi_{BA} = M \, dI_A$$

Integration leads to the result

$$M = \frac{N_B \Phi_{BA}}{I_A}$$

See INDUCTANCE MEASUREMENT [K V M]

Bibliography *See* INDUCTION ELECTROMAGNETIC

Inductance bridge

A device that compares inductances The induct ance bridge i a pecial case of an impedance bridge Just as the Wheatstone bridge is u ed to compare resistance the impedance bridge is used to compare impedances which may contain induct ance capacitance and re istance

General impedance bridge *A general imped* ance bridge is hown in Fig 1 Four impedances Z Z_b Z and Z_1 are connected into a quare array A source of voltage v is applied across one diagonal of the square and a detector or galvanometer G is connected across the other diagonal The bridge is balanced when the current through the galvanom eter and hence the voltage across it are equal to zero

If the voltage across G is equal to zero the in stantaneous voltage drop across Z_b must equal that across Z_1 If the instantaneous ine-wave voltages are equal they are equal in magnitude and are in phase with one another Equating the magnitudes $Z I = Z I$ and following the same rea oning $Z_b I = Z_d I$ The current in Z_b is equal to the current in Z because the current in G is equal to zero Similarly the current in Z_d i equal to the current in Z Eliminating I and I from the e equations an equation of balance is obtained

$$Z Z_d = Z_b Z$$

The voltage across Z leads I by the power factor angle ϕ and the voltage across Z leads I by the power factor angle ϕ If I leads I by the angle ϕ then $\phi + \phi$ must equal ϕ if the two voltage drops are to be in phase *Similarly* $\phi + \phi_b = \phi_1$ Eliminating ϕ from these two equations the econd equation of balance for the impedance bridge is obtained

$$\phi + \phi_d = \phi_b + \phi$$

Several important properties can be recognized by considering the second equation of balance If Z and Z_b are resistors with ϕ and ϕ_b both equal to zero then for balance $\phi_1 = \phi$ *This means that* Z and Z_d must both be inducti e or both capaci ti e for balance If ϕ and ϕ_d are both equal to zero the second equation for balance becomes $\phi_b + \phi = 0$ This means that Z_b is inductive and Z is capacitive or vice versa

General inductance bridge The inductance bridge of Fig 2 has resistors R and R_b as ratio arms and compares an unknown Z to a standard consisting of R_d and L_d If the standard L_d is variable it and R_d are varied to reduce the detector voltage to zero This balances the bridge and the equations of balance become

$$I / L_d = R / R_1 = R / R_b$$

Sometimes a ubstitution method is preferred In this ca e the balance is obtained as above with any good quality inductance for L_d The unknown i then replaced by a standard L in eries with R The bridge is balanced a second time by arying L and R When balance i obtained I equals I and R equals R_d For inductance standard *see* INDUCTOMETER

If the standard is not adju table it becomes n ce ry to vary one of the ratio arm R or R or both as well a R_d in order to obtain balance

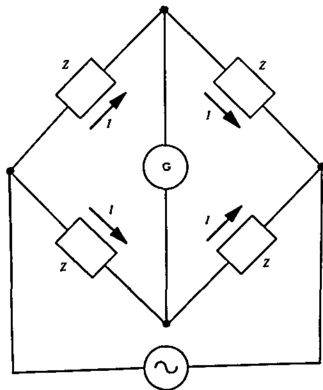
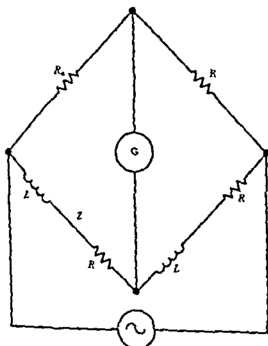


Fig 1 Ge e l imped ce br dge

Ob ı u ly the b t tuti method ann t be p- pl ed wher nly fixed tand rds ar ıa l lle

Theoret ally the d tı n for l lance ıs nde- pende t f f eque cy In p act e tl e c pa ıtan e betwe n t rn and b t een layer of w r ın the two c ıl w ll be d ffe ent d t high f eq n e th bridg can b bala ced at nl one frequ ncv at a tım Under ch ondıt n harm n c n the upply v lt ge w ll m ke ab olute balance mpos-



Fg 2 G l d ct c b dg

ble When harm nı s are pre ent the br dg h ld l e l alanced by redı c ng the fundam ntal mpo t ın the detector oltage to zero Thı cond tı n doe n t ne e arıly co re p nd to m nı mum dete to olta e A te hnıcıan can s m t mes achı a l ala e by ear at audı fr quen ı An o-cıllo c pe pr des a better mean f eeı g when the fu dament l l as beı n educed to zero

Anderson bridge Thı b ıdge hown ın Fıg 3 c n b u ed to mea ure the ductance L ın term of a t ndar l cap cıtance C Mo t lab ra t rıe hı n tock m re a ı bl capacıtor th n ı d ctometers A mea urement lepend ng upon ındu t mete s s more likely to be delayed tl n a me ur m nt depe d ng up n apacıtance be- ca s the app p ate ınd ctomete ı n t ava l able The equ t o s of balance of tl s br dge are

$$L_b = \left(R_d + \quad + \frac{R_d}{R_e}\right) R_a C$$

$$R_b + r_b = \frac{R_a R_d}{R_e}$$

The b dge ıs u u lly balanc d by varyıng r and C The ec nd equat on ndıcat that f r ome ch ıce of R R nd R n gat e r might be requ r d Con quently ıf a balan e does *not* e m p ble by aryıng C and r_b R or R hould b ncre ed or R should be ed c d Th wıll ın cre e $R\,R_d/R$ wh h ı need d be au e bal a ann t be btaı ed unless th s q antıty ı at l a t as la ge s R

Carey Foster bridge Thı eful l rıd f r de- t rmın g m t l ı ducta c ı h wn n Fıg 4 Th brıd ı tl et ally ı d pende t *of* fre- qu c) Wh n the bridge ı balan ed

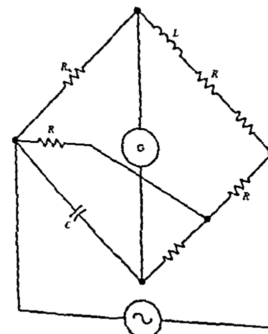


Fıg 3 And so b ıdg

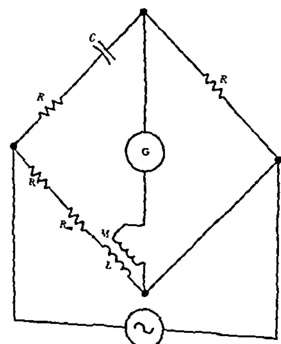


Fıg 4 Ca y F te b dg

$$M = R\ (R_M + R)C$$
$$L = (R\ + R\ )(R_M + R)C$$

If these equations are to be used directly the resistance R_M of the coil must be measured by some other circuit arrangement If a known large resistance R is connected in series with the coil it may be possible to neglect R_M in comparison with R and the equations become

$$M = R\ RC$$
$$L = (R\ + R\ )RC$$

Resistances R and R are varied to obtain balance An obvious advantage of this bridge is that all balancing operations can be performed by varying resistances The capacitance C may be a constant standard

Any discussion of impedance bridge operation should include mention of Wagner ground precautions Each portion of a bridge has a capacitance to ground as well as to all other portions In the case of high impedance circuits and at high frequencies these capacitances are not negligible A Wagner ground consists essentially of two bridge arms placed across the source with the common point grounded The Wagner ground is balanced to bring the detector terminals to ground potential When this is accomplished the stray capacitances no longer affect the balance or give spurious unbalance signals in the detector *See* IMPEDANCE MEASUREMENTS HIGH FREQUENCY INDUCTANCE MEASUREMENT [H SO]

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Inductance measurement

The determination of an electromagnetic parameter of an electric circuit The electric current in a circuit produces a magnetic field which is considered to consist of lines of magnetic flux that link the circuit Whenever the magnetic field linking a circuit changes a voltage is induced in the circuit The faster the change in the field the larger is the induced voltage When there is no ferromagnetic material present the magnetic field is proportional to the current i and the induced voltage v is proportional to the rate of change of current

$$v = L\ di/dt$$

The proportionality factor L is by definition the self inductance of the circuit If v is measured in volts and if the rate of change of current is in amperes per second the inductance has the dimensions of henries

The direction of the induced voltage is specified by Lenz s law which states that the current that would be produced by the induced voltage would be in a direction that opposes the change in the magnetic field Hence the inductance of a circuit represents the tendency of the circuit to resist a change in current This is analogous to the manner in which the mass of an object tends to resist a change in its velocity *See* INDUCTANCE LENZ S LAW

If the magnetic field produced by the current in one circuit links with another circuit the relation between the voltage and the rate of change of current still holds The proportionality factor in this case is called the mutual inductance *See* COUPLED CIRCUITS

If ferromagnetic material is present saturation and hysteresis effects may be evident for some values of current For such cases several definitions may be introduced or the concept may be discarded entirely An effective inductance is defined as the ratio of the effective induced voltage to the effective rate of change of current and is a function of the maximum current When the current changes about a certain average value and the magnitude of the change is small compared to the average value the above definition specifies an incremental inductance This inductance is a function of both the average current and the magnitude of the change

Inductance standards Coils constructed so that their dimensions and consequently their inductance remain constant over long periods of time are used as inductance standards If the dimensions are known the inductance can be computed from the formula

$$L = N\ P$$

where N is the number of turns of wire comprising the inductor and P is a proportionality coefficient Such an inductance is called a primary standard (*see* INDUCTOMETER) Standards are usually maintained at constant temperature to keep the coil size and therefore the inductance from changing in value

When the inductance cannot be computed precisely it may be measured by comparing it with a primary standard and it would then be called a secondary standard

The effect of inductance is manifested only when the current in a circuit is changing with time Any means of measuring inductance must employ changing current Usually the current is an alternating current of frequency f given by

$$i = I_m \sin 2\pi f t$$

with a maximum instantaneous value of I_m The voltage induced by the changing magnetic field is

$$v = 2\pi f L I_m \cos 2\pi f t = V\ \cos 2\pi f t$$

where L is the self inductance in henries The ratio of V to I_m is called the reactance of the circuit and is represented by X in

$$X = 2\pi f L = V\ /I_m$$

Impedance measurement This is the determination of the total effect of a circuit element Every inductance is wound with wire that has resistance This means that every inductance has resistance and conversely it is also true that every

res t r has induct nce G nerally mea urement t d t rmin the t d ctance of a c rc t t actually an mpedance mea r ment d g ves the re t t ance as well the t du tance See INDUCTANCE BRIDGE.

If the t cu t has r t t n R the total oltage d p t g n by the formula

$$v = RI_m \ \text{in} \ {\sim}ft + XI_m \ c \ s \ {\sim}ft$$
$$= ZI_m \ \text{in} \ ({?}{\sim}ft + \phi)$$

wh r $Z = \sqrt{R + X}$ is th impedanc f th cu c t a d ϕ s the phase a gle the p w r fac tor a gl f the t cuit g en by the el t on ta $\phi = X/R$

It mposs bl to con t ct an nducto with an hm c res t nc f z ro h we e by ca ef l de g n t po bl t minim e th resi tance for a g e am t f duct n e Th fa to of m rit f any ndu to s called the Q f th ndu t nd d fined as the rat f the r ctan to th effec t e resi t nc at y spec fied perating frequency

$$Q = \frac{\pi fL}{R_f}$$

Th effecti esi tan e R_{ef} rep es nt the c m b ed re sta e f th w r pl ddy-cu r nt l in the w r t the p cified per ting f e q cy The Q of a well-d gned r d o-f eque cy t d t r w ll be on th o d r f sever l hu d ed S Q a FTR

If the Q f t duct t high en gh that th ffect e resi tanc may be n gl cted th n t ght f rward ppl cati f Ohm law perm t mea u ng the ind ct n e d

$$L = \frac{I}{\pi fI}$$

M a me t of d tr b ted nd t n e of able l a d wa gn d t a mpl shed nd r tly F r y l w fr qu n es th c ble urr nts r d t b ted n f rml thr gh ut the onduct nd th ndu t p u t l gth max m m At h ghe f q n es th skin effect ca e th rr nt t e trat al g th nd t r u fa Th n ent ati d e t affect the m gnet c fi l l bet een th co d ct but t d es t nd to l m t th fi ld w th n a h ndu t it If Th edu t t m gn t field b gs bout ed ct n t d t Con q e tly a the f e q y n a ed th t d ct nc d e se p p a h g fi ed al

Th pa t n p unt l gth f able r pe w r t m n l n t d pendent of fre q nd be m a red at low f quen ies If d ert m m nt of tten t on nd veloc ty of p p g t r m d th nd t nce per u t length it m l m y b mputed t any f l of pe ti S ELECTRIC L MEASURE T [H O]

B bl g phy F A Law *El trical M* m t l ed 1938 M B St t *B c El tri al M a* m 1950

Induction electromagnetic

Th p oducti n of an electromot e f ce either by mot on of a nductor through a magnetic field in such a ma n r as to cut acr ss the magnetic flux or by ch nge in the magneti flux that thread a conductor *See* MAGNETIC FLUX

Motional electromotive force A charge m vi g pe pendi ula to a m gn t c field exper ences a fo ce th t i perpend cular t both the d r ction of the field and the di ection of motion of th charg In ny metallic conductor there are f ee el ctron lectr ns that have been tempor rily detached fr m th par nt atoms

If a c ndu ting bar (Fig 1) m es th ough a magnetic field each free electron experiences a f ce due to its m t on thro gh the field If the di re tion of the moti n is h that a *omponent* of the f rce on the electr ns is par llel to the conduc to th lect ns will m ve al g the conduct r Th electron will mo e ntil the forces due to th m tion f the ond cto through the magnetic fi ld a e balanced by electrostat c f rc s that ri e be au e elect ons c lle t t one nd of the c nductor lea ing a defi t of lectron at the othe Th e is thus an elect i field along the rod and hence a po t ntial diffe ence b tween the e ds f th od while th mot n continues A so n a the m tion stops the electr tat c f r s will au e the lectrons to eturn to the r norm l d trib ition

From th defin t on of magn t c induct on (fl x dens ty) B th fo ce o a harg q due to th mo t n f the charg th o gh a magnetic field i g en by

$$F = Bqv \ \text{in}\ \theta$$

wh re the force F s at r ght angl s to a pla e de t rmined by the d ecti n l the fi ld and the *om po ent* v in θ f the elo ity is p rpendic la *to the fi ld* Wh n B s in webers/m q is in c u l mb and v s in mete s/ c the fo e s n n w t s S I DUCTION MAGNETIC

Th lect i f ld int ty E d e to th is forc s g en i magnit de and d re ti n by the fo c pe u t po t e ch ge The electr field nten ty i qual t th n g t of th potenti l g ad ent along th rod I moti al lect mot e f r

Fig F d ty B mot d d ed emf $\mathcal{E}$ wh d ct of l gth l m f m fi ld (F m R L W b M W Wh d K V M g Phy t f S a d E g ee g McG w-H ll 1957)

(emf) the charge being considered is negative Thus

$$E = \frac{F}{-q} = -Bv \sin\theta = -\frac{\mathcal{E}}{l}$$

or

$$\mathcal{E} = Blv \sin\theta$$

where l is the length of the conductor in a direction perpendicular to the field and $v \sin\theta$ is the component of the velocity that is perpendicular to the field If B is in weber/m^2, l is in meters and v is in meters/sec the emf $\mathcal{E}$ is in volts

This emf exists in the conductor as it moves through the field whether or not there is a closed circuit A current would not be set up unless there were a closed circuit and then only if the rest of the circuit does not move through the field in exactly the same manner as the rod For example if the rod slides along stationary tracks that are connected together there will be a current in the closed circuit However if the two ends of the rod were connected by a wire that moved through the field with the rod there would be an emf induced in the wire that would be equal to that in the rod and opposite in sense in the circuit Therefore the net emf in the circuit would be zero and there would be no current

Emf due to change of flux When a coil is in a magnetic field there will be a flux Φ threading the coil the magnitude of which will depend upon the area of the coil and its orientation in the field The flux is given by $\Phi = BA \cos\theta$ where A is the area of the coil and θ is the angle between the normal to the plane of the coil and the magnetic field Whenever there is a change in the flux threading the coil there will be an induced emf in the coil while the change is taking place The change in flux may be caused by a change in the magnetic induction of the field or by a motion of the coil The magnitude of the induced emf depends upon the number of turns of the coil N and upon the rate of change of flux (*see* FARADAY'S LAW OF INDUCTION)

$$\mathcal{E} = -N\frac{d\Phi}{dt}$$

The negative sign refers to the direction of the emf in the coil that is it is always in such a direction as to oppose the change that causes it as required by Lenz's law (*see* LENZ'S LAW) If the change is an increase in flux the emf would be in a direction to oppose the increase by causing a flux in a direction opposite to that of the increasing flux if the flux is decreasing the emf is in such a direction as to oppose the decrease that is to produce a flux that is in the same direction as the decreasing flux

Consider the case of a flat coil of area A rotating with uniform angular velocity ω about an axis perpendicular to a uniform magnetic field of flux density B For any position of the coil the flux threading the coil is $\Phi = BA \cos\theta = BA \cos\omega t$ where the zero of time is taken when θ is zero and the normal to the plane of the coil is parallel to the field Then the emf induced as the coil rotates is given by

$$\mathcal{E} = -N\frac{d\Phi}{dt} = -NBA\frac{d(\cos\theta)}{dt} = NBA\omega \sin\omega t$$

The induced emf is sinusoidal varying from zero when the plane of the coil is perpendicular to the field to a maximum value when the plane of the coil is parallel to the field

Self induction If the flux threading a coil is produced by a current in the coil any change in that current will cause a change in flux and thus there will be an induced emf while the current is changing This process is called self induction The emf of self induction is proportional to the rate of change of current The ratio of the emf of induction to the rate of change of current in the coil is called the self inductance of the coil

Mutual induction The process by which an emf is induced in one circuit by a change of current in a neighboring circuit is called mutual induction Flux produced by a current in a circuit A (Fig 2) threads or links circuit B When there is a change of current in circuit A there is a change in the flux linking coil B and an emf is induced in circuit B while the change is taking place Transformers operate on the principle of mutual induction *See* TRANSFORMER

The mutual inductance of two circuits is defined as the ratio of the emf induced in one circuit B to the rate of change of current in the other circuit A For a detailed discussion of self and mutual inductance *see* INDUCTANCE

Coupling coefficient This refers to the fraction of the flux of one circuit that threads the second circuit If two coils A and B having turns N_A and N_B respectively are so related that all the flux of either threads both coils the respective self inductances are

$$L_A = \frac{N_A\Phi_A}{I_A} \quad \text{and} \quad L_B = \frac{N_B\Phi_B}{I_B}$$

and the mutual inductance of the pair is given by

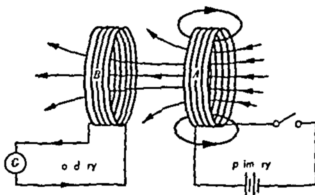


Fig 2 Mutual induction An emf is induced in the secondary when the current changes in the primary (R L Weber, M W White, K V Manning, Physics for Science and Engineering, McGraw-Hill 1957)

$$M = \frac{\lambda \Phi_B}{I_B} = \frac{\lambda_B \Phi_A}{I}$$

$$M^2 = \frac{\lambda_A \lambda_B \Phi \Phi_B}{I I_B} = \frac{\lambda_A \Phi_A}{I_A} \frac{\lambda_B \Phi_B}{I_B} = L_A L_B$$

or $M = \sqrt{L_A L_B}$

In g r l n t all th fl x f om ne circuit th e l the sec nd The fr ti n f the flux f om t A that th e d ir u t B depends up n th d t n e b tw n the two c r u t th r o i t t n ith respect t h oth r and the pre n e of ferr magn tic mate ial n the neighborh od e the a a c re as a h eld It f llows th t fo the gen e al ca e

$$M \leqq \sqrt{L\ L}$$

The rat f the m t l ndu tan e of the p i to th quare oot f the pr d ct f the ndividual M nd ta alled the oeffic nt f c u pl g K

$$K = \frac{M}{\sqrt{L\ L_B}}$$

The upl g efficı t h a m mum v lu f n ty if all the flux th ad both circu t z r f n ne f the flux f om o e i u t th d the oth F r all th nd ti n K h a alu between 0 a d 1

Applications The phe m o of l ctromag n t c i d ti n ha g t many imp ta t appl t o n mod rn techn l gy F ample e COUPLED CI CUITS GE ERATOR ELECTRI I DUC TIO HEATI G MI RO HO E MOTOR ELECTRIC SER IF HA I I [K V I]

B bl g ph S S Attwood *El tri and M g t F ld* 3d ed 1949 L P ge 1 N I Adams *P i pl f El t city d M g tism* 3d ed 19 9 F W Se *P cipl s of Phys cs* ol 2 19 1 R P W h *El tricity d M g eti m* 19 5

Induction electrostatic

A m thod h by lect i al o du t becomes lectr fied wl n h ged body It u f l es a se f m th f t th t f ev ry lect b rge tl e som h n eq al a d pp t i d d b g F d t l d d e ELECTROSTAT I S [R P W L]

Induction magnetic

A t q a t t th t i ed a a q a titat m f m gn t c fi ld It def ed i terms f th (e n a h rg m i g n th fi ld f om th q i

$$B = \frac{F}{q r \quad \theta}$$

h B th m gn t d of th m gn t du t l F i th f th h g q wh h m t c w th perd t i d ert n mal ng a gl θ w th th d ect f th fi ld Th d t l th ve t r q antity B is the di ection in wh ch th for e on the m i g charge i zer

The magn t indu tion may al o be pr ed in terms of the fo ce F n a urrent element of length l and current I That i

$$B = \frac{F}{Il \sin \theta}$$

The mks u it f magnet c i ductio is der ed fr m thi q at on by e pres n the fo c i newtons the current in ampe es and th l gth n meters Th u it f B s thus the newto /ampere meter

Magnet c flu den ity is the m gnetic flux per un t a a thro h a urface perpend c lar to the magnet c nduction M gnetic flux den ty and m g eti indu ti n a e two t rm that are equivalent S e MAGNETIC FIELD MAGNETIC FLUX

The magn ti indu tion may be r p e ented by l n s that a e d awn s that at e ery p nt i th f ld th t nge t t the li e t i th d rect on of the m gnetic ind ti n T repre e t the *magnetic* induction qualitati ly as many s ch line may be d awn a are eces a y to p rt ay th fi ld If how ever th l nes r to rep ent th magneti i d c t *on qu nt t ti* ly an a bitrary choice mu t be made f r the number of li es to repre ent a g ven c nd tio O e uch ho ce i that in which the num b r of lin per squa e m ter of urfa e j e pen dic l r to B et eq al i th v l e *of B* These l n s are called m n t c fl x O l ne f i du tio as her s lected is call d a flux of 1 webe The orrespond g un t of flux den ity is then the w ber pe q are meter Fr m th *m nne of defining* fl x ed he e t f llows that the web r p r qua e me ter i quiv le t to th newto /amp e-m ter

An th r u it of flux den ity is d fi ed by usi g nt met r g am e d (cgs) its both th de fi ng eq iat n f r magn ti nducti n and in the a which th re s unt fl x Th s cg nt of flux d n ity i c lled the gau The rel t o sh p between the gau s and the wel er s gi en by 1 weber/m = 10 ga es Se GAU S

F r d us n of an *im rtant* dev ce kn wn a b tatr whi h ut l ze the princ pl l ma net c *ind ct n* PARTICLE ACCELERATOR [K M]

B bl g phy E. P P ck *El ct city and M g n tism* 19 3 F W S a s *P cipl f Physic* ol 2 1951

Induction coil

A d i e fo pr du n l gh ltag ltern t ng urr t high olt g p ls fr m a l w oltage d re t c r nt Th la g t mod rn e of the i d t n c l th ig t n s t m of intern l mb ti n ngine s ch a n ut m b le gi e (s IGNITION SYSTE I) *De ces of* m lar n t ct n known as b ators ar ed s re t fi a d syn h o in rt rs (e VIBRATOR)

Figu 1 h w a typ cal irc t d gr m f an i d ct o l The p im ry l w i d n th o e o ts of o ly few turn Th econdary co l w d er th p mary co t f la ge mber f tu Whe the w tch S i I d th

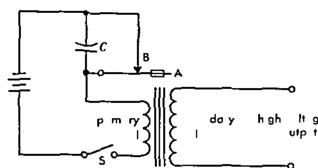


Fig 1 Typical circuit for an induction coil

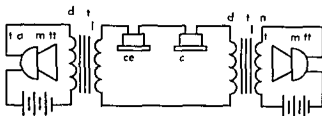


Fig 2 Induction coils in telephone circuit

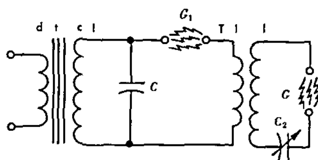


Fig 3 Circuit diagram of Tesla coil

iron core becomes magnetized and attracts the armature A This automatically breaks the circuit to the coil through contact B and the armature The armature is returned to its initial position by a spring and again make contact with the contact B restoring the circuit to the primary coil The cycle is then repeated rapidly

While current is flowing in the primary coil a magnetic field is produced When the contact between A and B is broken the magnetic field collapses and induces a high voltage in the secondary coil similar to transformer action (*see* TRANSFORMER) The self inductance of the coil must be limited therefore the core is a straight bundle of iron wires which minimize eddy current losses rather than a closed iron circuit as is used in a transformer

The capacitor *C* is placed across the breaker contacts to reduce the voltage across the contacts at the moment of their opening and thus reduce sparking Sparking is caused by the induced voltage in the primary winding resulting from the collapsing magnetic field The capacitor allows some of the energy of the magnetic field to be converted to electrostatic energy in the capacitor rather than into heat at the contacts

Induction coils of a different type are used in telephone circuits to step up the voltage from the transmitter and match the impedance of the line Therefore no interrupter contacts are necessary The battery and primary winding are connected in series with the transmitter as in Fig 2 The secondary winding and the receiver are connected in series with the line This circuitry reduces the required battery voltage

Still another type of induction coil called a reactor is really a one winding transformer designed to produce a definite voltage drop for a given current (*see* REACTOR ELECTRIC)

In 1892 Nicola Tesla used a form of induction coil to obtain currents of very high frequencies and high voltages The oscillatory discharge of a Leyden jar was used as the interrupter The terminals of the secondary of an induction coil are connected one to the inner coating and the other to the outer coating of an insulated Leyden jar C_1 (Fig 3) The circuit is completed through the primary winding of the Tesla coil and the primary gap C_1 The primary of the Tesla coil consists of a half dozen turns of wires wound on a nonmagnetic core The secondary consists of many turns The two coils are separated by air or oil as insulation The alternation from the Leyden jar may have a frequency of several million cps Hence the current induced in the secondary is not only of high voltage but also of very high frequency [C C]

Induction heating

The heating of a nominally electrical conducting material by current induced by a varying electromagnetic field

The principle of the induction heating process is similar to that of a transformer In Fig 1 the inductor coil can be considered the primary winding of a transformer with the work piece as a single turn secondary When an alternating current flows in the primary coil secondary current will be induced in the work piece These induced currents are called eddy currents The current flowing in the work piece can be considered as the summation of all of the eddy currents

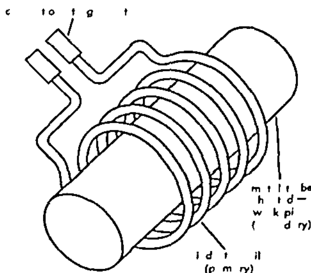


Fig 1 Basic elements of induction heating

In th des g f c n enti al f trical appa a t th l e d t d ed eddy cur e t e m nim zed beca e they reduc the r ll effi c ncy (*See* CORE LO S) H wever in d t on h at g th r max mum effe t s d ed The e f cl sp ng u d between th ind t r l and the wo k p ec and h gh c l urr nt a used t f t the m imum i du ed edd rr nt a d th f re h gh he t n r t

Applications I duct n h ati g i widely em pl ed n th met l w rking nd try to heat met l f ld ring brazing ne l ng harde ing and f r i d t n m lti g d i t g

A mpared t othe enti nal p oces es it h these inh r nt d t g

1 H at g nd ced d ectly into the m terial It i th ef a ext emely ap d method of he t i g It i t l r ted by th elati el l w rate of h t d ff t n m n enti nal p oces es u n ur f ee t ct ad a t h at g meth d

2 Bec e f k n effe t the he t ng s local ed a d the he ted e e ly ontr lled by th hape nd e f the nd t l

3 Indu t n he t ng a ily c ntr l bl e lti g in u f rm h gh q l ty f the p du t

4 It le d it elf t aut m t n. l e pro e i g a d aut m t c proces y l contr l

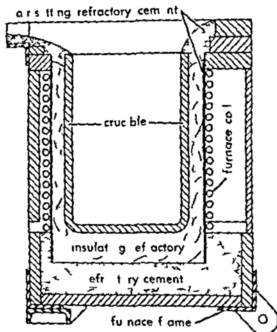
5 Start up time h rt and tandby lo ses a e l w non x t t

6 W k g o d ti are better b cau e f the al se e f n t fumes and radi ted he t

The induction heating process The ind c d rrent in th w k p e fl w oughly p rallel t th re t th d t r c l turn

Beca f th ki eff t these ind ced cu re t e t te n r tl fa e f the wo k p ece Th ffect depth f t pe et at n g t f l e f q e ies th n f h gh f e- q n d gr at f high e t ty met l th n f l w i t t m t l In m gn t m t l u b teel th d pth f cu re t penetr t n less b l w th C e te per t (pp ox m t l 1350 F wh th t el i mag t) than t bo th C e t mp ratu *S* CURIE TEM PR TURE & G ETIC SK EFFECT

F ff i h at g th f qu ncy u ed m t b h gh en gh t m k th d pth f c rr t p n t a t d ably l s tl th th kn f th



Fg 2 C ct f d ct m lt g f
(I d ct th m C p)

wo k p e m a ured at ght angles to the o l t rns The a c mpa yi table h th ra g f f equ n u ed for appl ations f the i d ct n heati g p ess *S al o* DIELECTRIC HEATING

I m s he t g appl catio s the l west fre- qu ncy c n tent w th effici nt h atin is d b a e as rul the n t al t of *quipment* g es up w th f equ nc

Whe th work p ec re all wl en t is de i ed t oncentrate tl h ti g n ar the u f ce as n s fa e h den g it n es ary to u e h gh r f eque c es e en thou h ffici nt p w r t an fe co ld be accompl h d at om l wer f e q n)

In la ge prod ction u e s h a f g g two pa ate fr quen i w th p r t i d ct co l a e mployed t ma ir ize prod ct on at min m m eq pm t c t

Power sources The eq ipme t u ed a pow r ou ces d p nd n the freq ency ange f r the appl c t o Wl l n f eq nc (ge e lly 60

Frequencies used in ind ction d dielectric he ti g

Frequ ncy f	So rce of pow	Lses
60 960	R t t g ge erators or co t rs	M ss nd t on heat n f f g ing f rm tru r p e- heat ng
960-10 000	M to -generator set	Indu t n he t g f m lt
10 000-60 000	C erters	h t treat g l h d
200 000 0 000	V cu m t be ocil l t rs	I d t l eatin f m ll scal m lt g nd t rin S rf ce du t n heatin f l raz ng sold ng h d ning
000 000-90 000 000	V cu m t be osc'l lators	d trip d w heat g D lect heat ng

cycles) are used suitable transformers power factor correction capacitors and control equipment are required

For higher frequencies up to 10 000 cps inductor type alternators are used These are usually driven by induction motors and are available in ratings from 7½ to over 300 kilowatts

Converters are u ed for the 10 000–60 000 cps range principally for small cale melting These produce the desired frequency by repeatedly charging a large capacitor from the 60-cycle line and discharging it through an output circuit tuned to the desired frequency The output is a train of damped *oscillations*

For frequencies above 200 kilocycles vacuum tube oscillators are used These are self excited and are complete with high voltage rectifier oscillator tank circuit controls and instrumentation When operating from a three phase supply they put out a continuous wave of rf power

Process use Induction heating is used for many heat processes as shown in the table The construction of a typical melting furnace is shown in Fig 2 (*see* FURNACE CONSTRUCTION) An induction heater u ed for hardening is shown in Fig 3

Induction heating differs from other methods of *heat treating in that it heats the metals very rapidly* and that holding time at hardening temperature approaches zero A minimum of time is therefore available for metallurgical reactions and this has a significant influence on the election of steel to be u ed *See* HEAT TREATMENT (METALS AND ALLOYS) For other electric heating methods *see* HEATING ELECTRIC [C.P.B.]

Bibliography D W Brown *Induction Heating Practice* 1956 G H Brown C N Hoyler and R A Bierwirth *Theory and Application of Radio-Frequency Heatin* 1947 J W Cable *Induction and Dielectric Heating* 1954



Fg 3 Manually loaded Ind ct on he ter for ha d ing of gears The gear Is loaded o a p dl d r the co l in the cente The sp dle ro es the g a f heat ng a d lowe s it I to a I que ch f ha de i g (West ghous Electr Co p)

Induction motor

An alternating current motor in which the currents in the secondary winding (usually the rotor) are created olely by induction The e current result from voltages induced in the secondary by the magnetic field of the primary winding (u ually the stator) *An induction motor operates* lightly below synchronous speed and is ometimes called an asynchronous (meaning not ynchronous) motor *See* SYNCHRONOUS SPEED

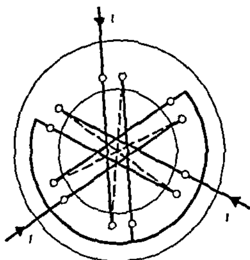
Induction motors are the mo t commonly u ed electric motors becau e of their imple construction efficiency good speed regulation and low cost Polypha e induction motors come in all izes and find wide u e where polypha e power is a ailable *Single* phase *induction motors are found* mainly in fractional hor epower sizes and tho e up to 25 hp where only single-pha e power is available *See* ALTERNATING CURRENT MOTOR

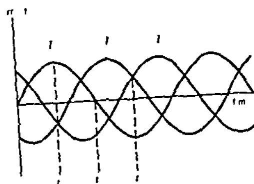
POLYPHASE INDUCTION MOTORS

There are two principal types of polypha e induction motors squirrel cage and wound rotor machines The differences in these machines is in the construction of the rotor *The stator con truction is* the same and is also identical to the tator of a synchronous motor Both quirrel cage and wound rotor machines can be designed for two- or three-pha e current

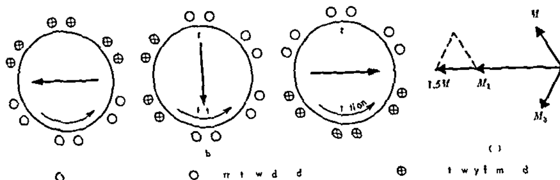
Stator The stator of a polypha e induction motor produces a rotating magnetic field when supplied with balanced polypha e voltage (equal in magnitude and 90 electrical degrees apart for two-phase motors *120 electrical degree apart f r* three pha e motors) The e voltages are supplied to pha e windings which are identical in all respects The currents resulting from the e voltage produce a magnetomotive force (mmf) of con tant magnitude which r tates at synchron u peed The speed is prop rtional t the frequency f the upply oltage and inver ely prop rti nal to the number of p le c n tru ted on the tat r

*Figure 1a i a implifed diagram of a three-*pha e two-pole Y c nnected tator upplied with currents I_1 I and I Fach stat r wi ding prod ice a pulsating mmf whicl varie in i lally will time The re ultant mmf of tl e three win ling (Fig 1c) i c n tant in mag it le an l r tate at synchron u p ed Figure 1f sh w tl lirecti n of the mmf in tl tat r f r tim t_1 t an l t_3 hown in Fig 1a and h w l ow tl e r ultant mmf





( )



O m t w d d ⊕ t w y f m d

Fg 1 Th ph d ct m t ( ) St t w d i g d u ts (b) R t t g fi ld (c) Mmf p d ed by t t w d g

t tes Th y h u p d N i

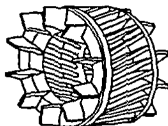
$$N = \frac{120f}{p} \text{ rpm}$$

h f th fr q n ycles p d a d p th n mb f t t poles F y g en f q f p t th s h u peed de t m ed b th mb of p le F 60 ycl f e q two-pol m t h synchr n u pe d f 3600 pm f p l m t 1800 pm a d o F d t l f tat wi d g Wi ni cs L T I III RY)

Squirrel cage rotor F gu 2 sh w the b f i g d wl g fi f qu el-c g r t r Th l r k ed gled t p ev t gg ng pe t g bel w yn l peed) nd t re- d se Th d g p d p th f r rrent th t h l m th lt g d ed the t r ba f s th t t fl Tl mbe f pol n t l-c g t al equal t th mber f pol ted by th t t w d g

F g 3 h w h w th tw m t r l ment t t N ro t lockw t t f th tat r fl x ause olt ge to be i d c d in the top ba of the roto a o tw rd d rection nd in the b t t m bars in wa d d ecti n Currents will flow i these b r in the ame d rection The e curre ts i ter t w th the tator flu a d p od ce f on the tor b in the d ect n f the t t n of the st t flux

Wh n t d i g l d th roto pp a hes ynchro u p ed N At this sp ed th is n mo- ti n f th flu with esp ct to th rot r conduc t As result, th r is no olt g induced in the



Fg 2 Sq l-c g t f i d ct m t

rotor and no rotor current flows As load is applied the rotor speed decreases slightly causing an increase in rotor voltage and rotor current and a consequent increase in torque developed by the rotor The reduction in speed is therefore sufficient to develop a torque equal and opposite to that of the load Light loads require only slight reductions in speed heavy loads require greater reduction The difference between the synchronous speed N and the operating speed N is the lip peed Slip s is conveniently expressed as a percentage of synchronous speed

$$s = \frac{N - N}{N} \times 100\%$$

When the rotor is stationary a large voltage is induced in the rotor The frequency of this rotor voltage is the same as that of the supply voltage The frequency f_2 of rotor voltage at any speed is

$$f = f_1 s$$

where f_1 is the frequency of the upply voltage and s is the slip expressed as a decimal The voltage e_2 induced in the rotor at any speed is

$$e_2 = (e \ )s$$

where e is the rotor voltage at standstill The reactance x of the rotor is a function of its tand still reactance x and slip

$$x_2 = (x \ )s$$

The impedance of the rotor at any speed is determined by the reactance x and the rotor resistance r The rotor current i is

$$i_2 = \frac{e_2}{\sqrt{r_2^2 + x_2^2}} = \frac{(e_2\ )s}{\sqrt{r_2^2 + (x_2\ )^2 s^2}} = \frac{e_2}{\sqrt{\left(\frac{r_2}{s}\right)^2 + (x_2\ )^2}}$$

This equation shows that for mall value of slip the rotor current is mall and pos e e a high power factor When slip becomes large the $r\ /s$ term becomes small current increa e and the current lag the voltage by a large pha e angle Stand till (or starting) current is large and lags the voltage by 50–70 Only in pha e or unity power factor rotor currents are in space pha e with the air gap flux and can therefore produce torque The current i contains both a unity power factor component i and a reactive component i The maximum value of i_p and therefore maximum torque are obtained when slip is of the correct alue to make $r\ /s$ equal to x If the value of $\ $ i changed the lip at which maximum torque is developed mu t al o change If r_2 is doubled and s i doubled the current i i not changed and the torque is unchanged

Thi feature pro ide a means of changing the speed torque characteristics of the motor Figure 4 curve 1 show a typical characteri tic curve of an induction motor If the re i tance of the r tor l ar were doubled without making any other change in the motor it would develop the characteri tic of curve 2 which shows twice the slip of curve 1 for any given torque Further increa es in the rotor resistance could result in curve 3 When r is made equal to x maximum torque will be devel ped at stand till as in curve 4 The e curves how that higher resistance rotors give higher tarting torque However since the motor s normal operating range is on the upper portion of the curve the curves al o show that a higher re i tance rotor re ult in more variation in speed from no load to full load (or poorer speed regulation) than the lo re i tance rotor Higher resistance rotors al o reduce mot r efficiency Ex ept for their characteri tic low tart ing torque low re istance rotors would be de irable for mo t applications

Fg 3 Force on the rotor w nd ng

Fg 4 Speed t rqu ch cte l t c f the polyphase nd ct o m to Curve 1 i f low i tance otor c nd tor C rv s 2 a d 3 a e f high ista c s of the to c d cto s Curv 4 is f r co ct r i ta c to prod c ma im m to que t sta d t ll (ma im m t rt ng to q e)

Wound rotor A w und rot r duct on motor can p o id both high t rt ng to que and good peed g lati n Th s ac ompl hed by adding xt rnal resi ta e t the r t rci c t dur ng t rt ing a d rem i g the re i tan e fter peed s at ta ned

Th w und r t r ha a polypha e wi di g im la t the tator w d ng nd m st be wou d f th same n mb f pole Voltage are induced in these w di g j t a th y ar in the qu rr l c ge r t bars The w nd ngs are con ted t l p r gs so that connect ns may be m de t t rnal mped n es u ually esi t t l mit tarti g curre t mp e power f ctor o cont ol pe d

F g e 5 ho the c nne t o f a rheo tat us d t br wo d r t r m t p t peed The theo-tat l mit th t rti g r ent d awn f om the up-ply t a alue less than th t r q i ed by a q rel c g m t r The resi t c gradu lly r du ed to br ng them t r up t j ed By le g a po t n f the t rt g res tan es n the cu t, ome

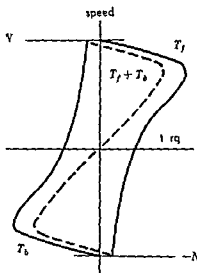


Fig 7 To q p d ed th gl -ph i d t m to

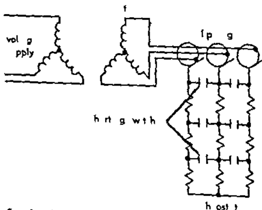


Fig 5 C ct f w d t d ct n m t

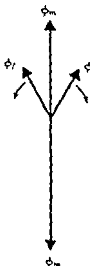


Fig 6 Fl sociated w th th si gl -phase i duc ion moto

d ee of speed ontrol an be bta ned a in Fig 4 H r th s m thod of sp ed control i inherently n ffi ie t nd o erts the motor i to a v ri ble-sp ed mot r r ther than an es ntially c n tant pe d moto For oth r mean of controlling sp ed of p lypha ind ct on m t rs and for other types of ac m to e ALTERNATING CURRENT MOTOR

SINGLE-PHASE INDUCTION MOTORS

S ngl phase ind ti n motor di pl y p o er p-e ating char ct ri tic than p lypha e m chines, b t a e used wh re p lyphase oltag s a e not a ail able They ar m t commo i small s z s (¼ hp o less) in dome tic nd indu tri l appl cat ons Thei parti ula d ad antag ar l w p wer fa t l w ffi ncy and th n ed f spec al ta t ng d ic

Th rot r f a ngle-phase ndu tion motor i of the sq irr l cag type Th stat r ha a main wind g whi h prod ces puls tin field At t nd t ll th p l t ng field ann t p d e oto u rents that will a t th ai gap fl x t p od ce rot r to que H wev r nce th ot r i t rn ng it pro-du es r s flu at r ght a gles in both pa e nd t me w th th ma n field and thereby p d ces ot t ng field comparable t that produced by the st t r of a two-ph se m tor

An e planat n f th is ba ed n the con i t that a pulsati g field i th equivale t f two p p itely rot t ng field of on *half* the magnitud of the es ltant pulsat g fi ld In F g 6 ϕ_m s hown ly by ts two components ϕ_f a d ϕ whi h s rep esent th two oppos t ly r tati g fi ld f con t t equ l m gn t des of $\phi_m/2$ Ea h c mponent ϕ_f a d ϕ pr duc t qu T_f nd T n the t Figu e 7 how that the um of the to ques is wh n peed r Howe r f sta ted th m of th to ques s not e a d r tation will be m i ta n d by the resulta t t que.

This machine has good performance at high speed But to make this motor useful it must have some way of producing a starting torque The method by which this starting torque is obtained designates the type of the single phase induction motor

Split phase motor This motor has two stator windings *the customary main winding and a starting* winding located 90 electrical degrees from the main winding as in Fig 8*a* The starting winding has fewer turns of smaller wire to give a higher resistance to reactance ratio than the main winding Therefore their currents I_m (main winding) and I (starting winding) are out of time phase as in Fig 8*c* when the windings are supplied by a common voltage V These currents produce an elliptical field (equivalent to a uniform rotating field superimposed on a pulsating field) which causes a unidirectional torque at standstill This torque will start the motor When sufficient speed has been attained the circuit of the starting winding can be opened by a centrifugal switch and the motor will operate with a characteristic illustrated by the *dashed curve of Fig 7*

Capacitor motor The stator windings of this motor are similar to the split phase motor However the starting winding is connected to the supply through a capacitor (Fig 9*a*) This results in a starting winding current which leads the applied voltage The motor then has winding currents at standstill which are nearly 90 apart in time as well as 90 apart in space High starting torque and

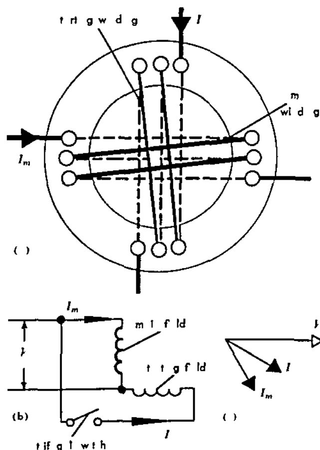


Fig 8 Split phase motor (a) Windings (b) Winding connections (c) Vector diagram

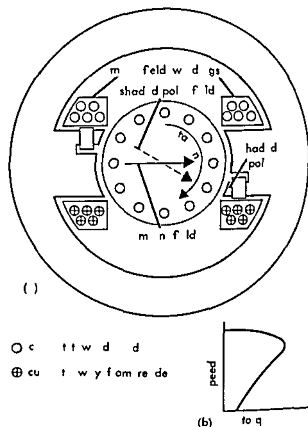


Fig 10 Shaded pole motor (a) Cross sectional view (b) Characteristic

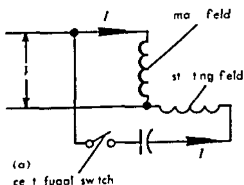


Fig 9 Capacitor motor (a) Winding connections (b) Vector diagram (c) Characteristic

h h power fact ar ther fo btained The tart ing winding ci cu t an be pened b a centrifu al w t h wh n the m t r mes up to peed. A typ cal h a teri t is sh wn i Fig. 9c

In som m tors two ap c t rs are u ed When the m t i fir t connected t the lt upply th two pa t rs are sed i parall l in the start g c rcu t. At h h peed on capacit r i e m ed b a entrifugal w tch le in the other in series w th the t rti g winding Th m t r has h gh tart ng t rqu a d good pow r f ct

Shaded pole motor Thi m t r sed exten iv ly whe e l rg powe and larg tart ng t rque are ot requ red a i fa A sq irrel-ca e rotor s used w th a al nt pol tat r xc ted b th a pply Each al nt pol i l tted o that a po tio of the pole face can be en led by a hort rcu ted w d ng r had n o l

The m in windin produ es a fi ld between th poles as n Fig 10 Th had g coil act to d lay th flux pa i g thr gh them so that it lags th fl x n th u h ded p rti ns Th gives a weeping magnet act n ac os th pole f ce and con qu tly a ros the rot r bars oppos t th pole f c nd result a t que on the r t r This t qu is m h maller th n th to q f a pl t pha e mo to but t dequ t for m ny perati n A typ l h ct ti i h wn in Fig 10b

For the ingle-pha e ltern ting-current mo t s s e REPUL O MOTO U IVER AL MOTO For syn hr nou m tors b ilt fo le-phase e HYS TE E IS MOTO R LUCTA CE MO OR. [A G C O]

Bibl g phy A F P ch te n. T C. Ll yd. and A G Conr d *Alt at g-c t M h es* 3d ed 19 3

Inductometer

A l fwi e f k wn ind t e Th ind ctan m y be f ed a th e of primary st nd rd r th nd ta m y be adj tabl by means of t hes co t n u l ari bl by means f a mov ble c l n tructi n.

F d l w tates th t th ltag ind ed n a r t p port l t th rate f ch ng of m gn tic fl x. F r fl x ϕ link g N t rns of a cu t

$$= N\frac{d\phi}{d}$$

If th s n f rromag et c mat ri l present, th fl x ϕ i p port n l t th m gnetom tiv fo e M

$$\phi = PNI$$

Th proport n lit fact r P alled the perme ce f th fl p th d I is th e t p g th gh th co l. Th te of ch ng of flu is equ l t NP t mes th rat f hang f urrent

$$= NP\frac{dI}{dt}$$

Bec se th p portio l t f ct t th equati n d fined th d ta L

$$L = N^2P$$

The formula, so deri ed, a umes that all of the fl x link with all of the current In reality there i som flux that link with nly part of the current When the f rmula i c rrected to include partial linkages N and the perm nc f th path of the flux that enters int the part al linkages a well as th complet link ges N

$$L = N^2P + N^2P$$

A tandard inductan e i co tructed by winding a co l n a f rm having dimen i n that re table Some m terial dry o t ab-orb moi tu e over the years and co seq ently han continu u ly in siz The materi l on which a tanda d indu tance i wound mu t not be bject t uch chan M rble a d ome ynth tics h ve been found suitable A hel al groo e is ut in th mat ri l, and th co l i placed in th s groo e

Th wir h uld be soft enough to onform to the groo It h uld be anne led so that the esi tivit and th current den ty are un f rm Th co l and t f rm are maintained at on t nt temperature to educ th tendency f r apid ind ctance aria ti n. The material selected f r the *form* sho ld h low t mperatu coeffic e t f expan n in add t on t negl ble l ng period hange n size

If the magn t c fi ld produced by the current in uit link w th an th r c rcuit, the voltage—ate-of-change-of-curre t lati n till h ld The pr port nality f ct r in thi ca e i called the mutu l ind ctan e between the two i cu t Th mutu l ind ctan e represented b the s mbol M i ev dentl

$$M = N N P$$

wh r N_1 and N re the numbers of turn in the respective ircu ts th t link with the c mm n flux nd P i th perme n e of the p th f the om m n flux Th m t al ind ctance i often written

$$M = k\sqrt{L L}$$

wh r L and L r the self ind ctances of th divid al circu t, and k number less than un ty alled th co pl ng coeffici nt.

Thes equati ns with th formula f r self induct e give

$$P P_2 = k P$$

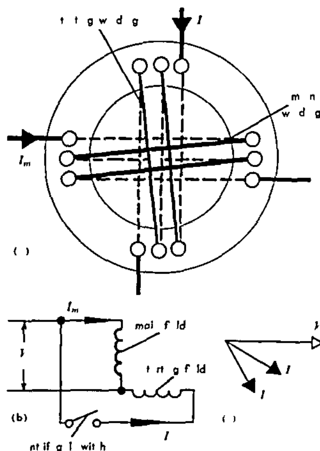
w ere P_1 t the permea ce of th p th f r flu p od ced b on ci cuit and P is the perm ance of t e path f r th fl x produ ed by the othe ir uit. If there w e n leak g flux, P_1 P nd P_{12} would ll be equ l, and k wo ld be un t

Campbell standard mutual inductance This ha a primary wi d g cons ting of two coil placed a cylindrical f rm milar t that used fo th ta dard self ind ctance. On wi d ng i pla ed in th groove ne r ea h end f the f rm. The es ling pace between th coil i adj ted so that the m gneti fi ld p od ced by n o l will e actly anc l that produced by th the on

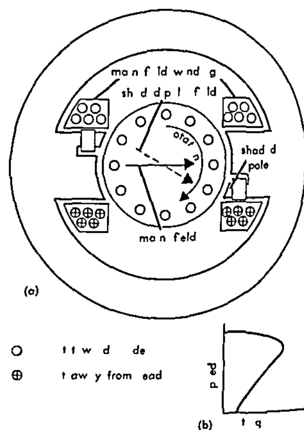
This machine has good performance at high speed But to make this motor u eful it mu t have some way of producing a starting torque The method by which this starting torque is obtained designates the type of the single pha e induction motor

Split phase motor This motor has t o stator windings the customary main winding and a start ing winding located 90 electrical degrees from the main winding as in Fig 8*a* The starting winding has fewer turns of smaller wire to give a higher re sistance to reactance ratio than the main winding Therefore their currents I_m (main winding) and I (starting winding) are out of time phase as in Fig 8*c* when the windings are supplied by a com mon voltage V The e currents produce an elliptical field (equivalent to a uniform rotating field uper impo ed on a pulsating field) which cause a uni directional torque at tand till Thi torque will start the motor When sufficient speed has been at tained the circuit of the starting winding can be opened by a centrifugal switch and the motor will operate with a characteri tic illu trated by the dashed curve of Fig 7

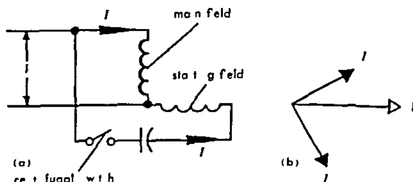
Capacitor motor The stator windings of thi motor are similar to the plit pha e motor How ever the starting winding is connected to the upply through a capacitor (Fig 9*a*) This re ults in a starting winding current which leads the applied voltage The motor then has winding currents at standstill which are nearly 90 apart in time a well as 90 apart in space High tarting torque and



Fg 8 Spl t phase moto (a) W d ng (b) W nd g connect ons (c) Vector d agram



Fg 10 Shad d pole motor (a) Cross sect onal w (b) Cha act ristic



Fg 9 Cap cito moto (a) Wi d g con ect o s (b) Vecto d ag m (c) Cha acte i tic

high po e fa t ar th ef e obtained The tart n winding irc t a b pened by a ce t ifugal s t h when th mot c mes up to peed A typ al cha t tci h n F g 9c

In me m tors tw p c t rs are u ed Wh n the m t r fi t ected to the olt g pply the tw apa to ar u ed par llel in the tart g c cu t. At h gh r peed n c p c t r i e mo ed b nt f g l wit h l ng th ther in ies with the ta ti wi d ng Th mot ha high tarting t rque nd g od powe f ct r

Shaded pole motor Th m t i used exten iv ly whe e la g p wer d la ge starting t rqu ar t equ ed s in fa A quirrel-c g t i sed w th a li nt pole tat ex ited by th a pply Ea h alient pole s lotted that po t n of the pole face a be en led by hort c cu ted w d n h d ng oil.

The main windi prod c s fi ld b tween th pol in F g. 10 Th had n co l ct to d lav the flux pa ng thro gh th m s that it lag the fl th u h ded port This gi es sweep g magneti cti n ac os the pole face, nd c nse qu tly a os the ot h rs pp it th pole f c and result n a to que th t r Th t que is m h maller tha the t rq e f a pl t ph s mo to b t it is d q at f m ny ope ti s A typ al ch r t ti h wn F g 10b

F r ther ingle-pha e alt rn tin -current mo t REPULSIO IOTOR U IVE AL MOTO F r yn hro u m t s b ilt f in le-pha HYS T ESIS I OTOR RELUCTANCE MOTOR [A G CO]

B bl g phy A F Pu h t T C. Ll yd and A G Co ad *Alt att g-c e t M h n* 3d ed 19 4

Inductometer

A il f wi f k wn ndu t Th ind ri m y be fi ed a in the a e f p m ry ta d d r the ind ta e may b adj tabl by me of sw t hes, o t u lv v riabl by m an of a m bl -e l c tri t n

F aday s law t tes that th lt ge nduced n t p p rti n l t the r te of cha ge f magn t fl x. F r fl ϕ l nki g N t rns f c cu t

$$= N\frac{d\phi}{dt}$$

If th f rr m gn ti m t ri l present, the fl ϕ p port l t th m gnetom t f e NI

$$\phi = PNI$$

Th p porti n l ty fa t P alled th perme n f th fl p th nd I th cu t p g thr gh th l The r t of h g f fl x s qual t NP t mes th te f ch g f urr t

$$= N^2P\frac{dI}{dt}$$

Bec u th p port al ty f ct r n this eq t on d fi ed a th d t L

$$L = N^2P$$

Th formula o der ed a mes that ll of the fl x li k w th ll f th c rr nt In reality th re i s me flux that l nks with nl part of the current When the form l c rrected to i cl ide partial l nka es N and the perm anc f th p th of th flux that e t rs into th partial linkages well a the c mplete l nkages N

$$L = N^2P + N^2P_p$$

A tandard ind ctance i con tructed by wind ng il on a f rm ha ng dime i n that are table Some material dry o t r bsorb m i tu e er the ye rs a d q ently change o ti u ly in ze The materi l on which tand rd i ducta ce i w u d mu t not be s bject t h ch nge Marble a d som synthet cs ha bee found u table A h li al groo i c t n the mate al and th c l is pl ced in th s groo e

The wir h ld be softe ugh t c nform t the groo e It h ld be annealed so that th resi t itv and th current den it e unif rm The coil and t f rm a mainta d t con tant tempe ature to r d the tendency f r rap d i d cta ce ar a t o Th m ter al selected fo the f rm h ld ha a low tempe tu e oeffi ent of p n in add ti to n gl gible l g period ch g n ze

If the magnet fi ld prod ed by th current i ne c rcu t links with a oth r c r u t the oltage-ate-of-ch nge-of-c rent rel t n i ll h ld The p port onal t f cto in this c e called th m tual i d ctan between the two ci uit The m t al nd ctance rep esented by th symbol M is ev dently

$$M = N N P_2$$

wh re N a d N are th n mbe s of t rns in th respecti e circu t that li k with the comm n flux d P_2 s the perm a e f the p th f the com mon fl The m t al ind t ce is ft n writt n

$$M = k\sqrt{L L}$$

wh r L_1 a d L are th lf ndu t es of the nd vid l t and k is a n mbe les than nity lled th upling coeffic ent.

These q ti w th tl e f rmula for self ind ct gi e

$$P P = k P$$

wh P th p rm e of the path fo flu p oduced by n c uit nd P i the perm n e of the p th f r the flux p odu ed by the th cir cu t If the w e n leakag flux P P a d P w uld ll be qu l a d k would be *nity*

Campbell standard mutual inductance Th h s a p imary winding con t ng f tw ils pl ed n a cylind r l f rm imila t that u d f th t nda d lf indu t O e w nd ng is pl ed in th groo n e h d of th form The e ulting p c between the c l adju ted o th t the magn ti fi ld prod ed by o o l will x tly cancel that p odu ed by the ther n a

ring concentric with the upporting cylinder The flux density in the neighborhood of this ring is very low A secondary winding is placed on a form that supports it centered as nearly as possible on the zero-field ring Any inaccuracies in placement of the coil or subsequent slight di placement will have nearly negligible effect on the flux enclo ed and con equently upon the mutual inductance

Ayrton and Perry inductometer This inductom eter consists of two coils (see Fig 1) One is *wound on the outside of a spherical form the* other is wound on the in ide of a pherical form The first coil on its form is placed inside the econd coil on its form The inner coil can be turned through 180 to change the direction of the mutual linkages and the sign of the mutual induct ance If the two coils are connected in eries the effective inductance is equal to the sum of the self inductances plus twice the mutual inductance

$$L = L_1 + L \;\; + 2M$$

The spherical forms make it possible to have the individual inductances as well as the maximum

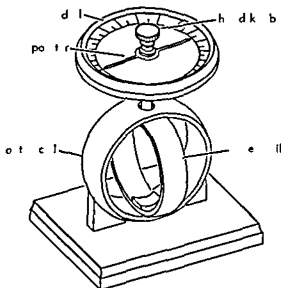


Fig 1 Schemat c draw ng of Ayrton a d Perry var a ble i ductomet r

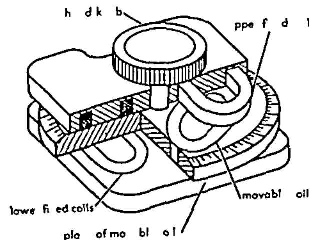


Fig 2 Schemat c drawi g of B ooks iabl i d c tomet

mutual inductance all nearly equal This tends to increase the maximum effective inductance of the series combination More important it re ults in a minimum effective inductance of nearly zero A di advantage of this construction i that the calibra tion of the effective inductance L for angular dis placement θ between the two coils i irregular Interpolation is always unsati factory with an ir regular calibration Linear interpolation generally cannot be u ed If the scale is always et on a *calibrated point to avoid interpolation the in* ductometer in u e is no l etter than one that is varied by mean of switche

Brooks variable inductometer This inductom eter provides a nearly linear cale It con i ts of four fixed coils and two movable one (ee Fig 2) The two movable coil side by side in a plane are sandwiched between two pairs of fixed coil With the movable coils directly between the fixed coils the mutual inductance is a maximum By mo ing the coils in their plane so that the coil previou ly between two particular coil i placed between the other two coils the mutual inductance is again a maximum but its sign has been changed As in the Ayrton and Perry device the eries connected inductance is

$$L = L_1 + L \;\; + 2M$$

By using link shaped coils of special de ign it is possible to obtain an inductance who e calibration is quite linear over most of the range The calibra tion departs from linear a slight amount near both ends of the scale

The sandwich type construction of the Brooks inductometer contributes to the tability of its calibration Any tendency for axial di placement of the movable coils from two of the fixed coils will be accompanied by a similar displacement toward the other two fixed coil making the net change in mutual inductance negligible *See* INDUCTANCE INDUCTANCE BRIDGE INDUCTANCE MEASUREMENT

[H SO]

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Inductor

A device for introducing in luctance int a circuit The term covers devices with a wi le range of u es size and type including component f r electric wave filters tune l circuit electrical mea uring *circuit and energy torage l ic*

Induct rs are cla ifie l a f xe l lju tal le and varial le All are ma le e ther with r with it mag n tic c re Induct r without magn tic c re are calle l air-c re coil although the actual core mate rial may l e a ceramic a pl ti r me ther n nmagnetic material In l ictor with m gn tic c re are call l ir -c re c il A wi l vari ty of m gnetic materi l i u l a l w m f tl c tain ry little iron Magnetic cor f r i d ct r for l w fr qu n y r l igh en rgy t rag use are mo t omm nly ma l fr m min ti n f

T d I I

l c n ste l Some ı n-co e ndu tor with res of c mpr ed p wdered r n p wde ed pe malloy r fe t m u table f r higl er fr quen y ppl c tons

Fixed inductors In fix d du t r co ls r wo d so th t the t r s r ma n fi ed n po t n with pect to a h other If an r n c e ı used a y a r g p t has ı also fi ed and the pos t on of th co ma n n h ged w th n th o l

A t roid l oil fix d ı du tor w und un f rmly a nd a t dal f rm Bec u e of the cl d magn t c e cut, u h an d t r has p a t lly n leak ge fl and ı lıttl ffected by the p es nc of t y magnet c field H gh c u acy t nd d du t a ommonly made th s f rm Powered co re u ed to ı ease th Q f th o l nd educ th ıze eq red f r a sp c fied ı d ct n Cer m c tor ıdal co l pp ried o k re sed as tanda d duct r of h gh tabil t nd ccu acy

Adjustable inductors The either ha e tap f h ng ng th umb r f t rns d d, r c n t f e al fi ed nd tor which may be t h d t arou er pa allel omb na ıı n

Variable inductors S h d t s n t u t d so th t the effect nd ct nc ca b ha g d M s f r d g th el de (1) ha g g th p rme b l ty of a m gnet c c (2) m v g the m gn t c c p t f ı, w th re pe t t the co l the r ma nde f th o e nd (3) m g m e c ıls f the ndu to w th espect t n m of the oth c ls th r by h g g m t al du t n S A TER TIV CURRE T RCUIT H ORY I DUCT NCE

[B L R W S P]

Industrial control

Co t d b dg t nt l p ocedu es mport nt lem ı f ı d t l c t l I d tr al ı l p p ly d d ıı ted ı r l t n t the sev l lev l f m n g me t, n bles p fit bl oper t on ı compet t fi ld a d res a c m p y s abl ty t dju t t ı d try h ng d t g l ec m t t

Cost control U f c t a u tı g f c ntrol d es f m th b l ıty ı d t rm t ın te ms f t n a s d p oduct, p t or p ocess a d ı mp thes ts t predet m ned est m tes o tandards The m re comm n st systems are j b or o de c t product c ts proce co t and tandard t

With j b o rd r c t each cust mer s order translat d ın turn ınt a plant production order ıs d t rm ıned eparately fr m all other order Charges f r dı ect material and d rect labor are r c rded agaın t the plant order tog ther with bur d n n the l a s of dı ect labor d llar d rect labor ho s or machine hou s The jol or der co t system ı ed p nc pally ın jobl ng h ps ın whicl the nd ıdual rders vary greatly

Product-co t system ıs employed ın c mpanies wh ch prod ce a l ne of regular products Cost may b determ ned by part number and l y opera tı n Final un t c ts a e obt ı ed b dı ıding the gg gate mate ıal lab r and l urden costs by qu ntıtı s prod ced

Process co t ı ppl cable to proce pl nts ın th ch mıcal mı ıng pap r and m lar ındu tries The th ee elem nts of co t (mat r al labor and b de) c n be dı ıded by a c mmon unit f mea u e s ch as pou ds feet or gallons Such u t p c s c st can be de eloped f rther by opera tıon

Sta dard c sts a e b ed o *predetermined* co t sta d rd uch osts m y be u ed ın a y of the f reg g system alth ugh nly ın egment f the u ual j b-cost system Standa d cost e defi ed as th appl cable t n rm l produ tıo taking ınto acco nt cu r t nd a t ıp ted cond tı ns which w ll affe t ope atıon Mat rıal ost t dard a e d el ped n the ba ıs f spec fic tıo s con ump-tı n and p es t and futu e pric Labor cost t nd rds u ually ar determı d f om related time t d es P ed termined dep rtm ntal b den rates a e lculated on the bas f co dıt ns e yected t *preva l* St nd rd st j roced res nd the n f rm t e a nce accou t which can be devel *oped* u ref m e f g at al e ın c ntr ll ng c t a d ımp g ope atıng effi ıency

Budget control Co trol f any c nt nu g ac t ty f tered by b dg tary procedures th at ge te the f llow g d nt es (1) u d g al ( ) op tıng plans rd ated with f n n l u ce (3) ts a t l f r ımp oved c n trol (4) a m nım ım of w teful nd haph rd op at n (5) sou d pla ng based on enf ed e amn t n f f t re c ndıt ons d (6) c m p n f tual pe f ma ce w th pr mıses nd p ed t mined est mates B dg ts a e n me ou ı h cte and ın th r ppl b lıty t arıous a t t es th y a e used d ffe e tly by arıous level of ma agement A l udget ıs n estimate usually f m ney wh ch will be p nded for cert n pu p es w th n *specified* pe ı d f time A fo ec st u ually pıl e t m g al e t m t s sım lar to a b dget b t o e g l g r f t p ıods O all nt gr ted b dg t a e a u ly de c bed b dgeta y c t l s p og mmı g mply as c ntr l

An feme t of f nd me tal ımp t ce t budget nt ol l es ı the p y hol gy mpl yed ı th d

ring concentric with the supporting cylinder The *flux density in the neighborhood of this ring is* very low A econdary winding is placed on a form that supports it centered as nearly as possible on the zero field ring Any inaccuracies in placement of the coil or subsequent slight di placement will have nearly negligible effect on the flux enclo ed and con equently upon the mutual inductance

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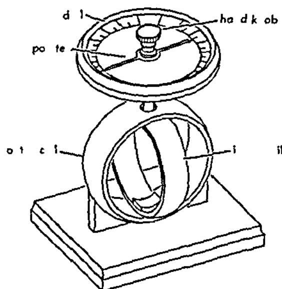
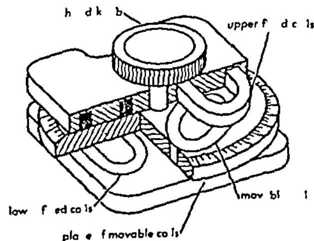


Fig 1 Schemat c d aw g of Ayrton and Perry a ia *ble nd ctometer*



F g 2 Schemat c drawi g of Brooks va iable ind c *tometer*

mutual inductance all nearly equal This tends t increase the maximum effective inductance of the series coml ination More important it results in a minimum effective inductance of nearly zero A disadvantage of this construction is that the calibra tion of the effective inductance L for angular di placement θ between the two coils is irregular Interpolation is always unsatisfactory with an ir regular calibration Linear interpolation generally cannot be used If the scale i always set on a calibrated point to avoid interpolation the in ductometer in use is no better than one that is varied l y means of switches

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[H SO]

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Inductor

A d vic for intr ducing in luctan e into a circuit Tl e term cover levice with a wi le range of u e size and type inclu ling omponent f r electric wave filter tune l ircuit elect i al m a uring circuit and energy t r g l i

In l ict r are cla f e l a f xe l a lj i tal le and varial le All are m le eith r w th r witl ut mag netic c re In luct r without m gn ti ore ar calle l air c re coil altl ugh tl ti al c r mate *rial may l a ceramic a j la ti r s me tl er* nonmagneti *material In l i tor with magn ti* core ar call l iron c r il A wi l ari ty of magn tic mat rial i u l an l s n f tl contain v ry little ir n Mag ti c res f r in duct r f r l w fr q ien y or l igl en rgy t r g use are m t c mm nly ma l fr m l minati n f

ti n a d t me l s can be e tabli hed for each moti With t bles f mot on t m data t i pos-s ble t d t rmi the time equ ed to p rf rm m n al ta k

Wo k s mpl n Work amp l ng employs the and m mpl g theory The p rcentage of a w rk ng d y th t an op ato i w rk ng is ba ed pon the perc t g mb f b ervati ns wh ch *rero d the op r to s wo ki g* Th method gi e a reliabl m ur f the pe entage t m that th perat r workin f suffici nt ob rv t ns ar taken By es l at ng th pace of the ope ator wl n h is ob rved t be wo k g and by rec ding the *n mb r of t n t f w k p* oduced during the study it i *po ible to* d term ne tandard t m for an p r h

Becau time tanda d appl es only t a spe fi pe at n t s nec s ary that the ope at on b standardi ed a d that a d ta l d writt n descr i t n f it ppl me t th time t nda d A m plete m thods des ipt on i impo tant that gh t graph r m ti n p tures re sometimes us d t pplement the writt tanda d p actice

In m ompan es the ind t al *ngi eer ng d p rtm* t l a mes om r all resp ns bility for el ct ng pur h g a d t ll ng new fac t ry q ipme t d gn g t ol ng and fixtures d t rmi ng n pect on pro edur a d adm n t c ng qual ty o tr l The indust al eng nee ng de p rtm t m y al o b esp nsible f r u h fu c t as j b ev luatio packag ng ng e ing fice-l rms c nt ol mat r l handling d pl t l y ut

Organization I du tr l ng ee *ng is u ually* pla d n it m n l tu ng rg zat altho gh it m t m f und the ind t al relati or fi c l d i n A rvey of 100 c mpan es h wed that n 68% f the ca s *the ch f* indus-t t l g ported d ectly to the general m ag fa t ry ma g r i e-pe d nt f *man la tur* g

I som c mpa es, ind tr al g n er g a t i ties e all pla ed n ingle ind t l g n eri g d partment wh l n th r firms the ndu t al n g ne ri g a t ities e dec ntralized Fo exampl offic m th ds and proced a d yape w k m pl fi at n m ght be dm n t red by the offi m ge mat al o t r d t in p ogr m by th p es ng nee d m thods a d m u ement f t ry wo k n the m ufa tu g di i n H w i c mp n e ha ng wag incent p gram t me t d d el ted a t v t re n ly lw y o t ned in a ingle d p tment. M y t t es of the nd tr l gi f ll w d fi te p oced e d some e uti e H w m thod mp v m t pr j ct and sp ci l tud es u ll t k the fo m of a pec fi s on m nt w th b dg ted st establ hed and mple t n dat pecified

I d t I g e g p *I* M st omp es pr f i d t i l eng ee wh ha eng nee ing degree pref ably in nd tr l ng ee i g h wev bus nes adm t t and I b al rt graduates are ometimes employed The larg r mpa es have s me people with advanced de-gr es Thor ugh traini g in t ti ti s and *mathe-*mati s i bec ming incre singly es e tial A urvey of 100 ompan es with indu trial engineering de-partment howed that 43% *of the indu trial* en gine rs are college graduates and 21% a e people wh were taken f m the hop and trained in in du trial eng neering

Pa t c pat on i cos reduction The w rk of the industri l engineer early always results n cha ge When a bett r method i pr posed new ma hine n w q ipment r n w procedures *may be called* for and s the operat rs are a ked *to change* th way th y l a e been doing th ng If *properly* ap-p oached th cooperation of the affected people an be ol tained *If th* people who will b affected by a change part c pate in developing the new meth d and have a part in putt ng the change into eff ct th y a m re likely to s pport the change th n if it is *impo ed from* outside In line with th philosophy pervi ors and workers a e encour aged to m ke s ggestion for mpro ements and w th the aid f the indu tr al engin ering *depart m nt,* t put them to effect.

Te m goal app a h Participation can l e car ried to a d partment or a pla t with *many people* acting a a team to establi h a go l a d then etting out to reach t Th i du tri l e g nee ing depart me t then rve as f ct f nd ng agen y and pro-vid taff ervic a r qui ed Thr ugh o ga izing thi g so that th rs take the *in ti t* e for mak g ch ng and by perfo ming q ckly and p fici ntly those duties that e equired of him by the op-erat g *pe sonnel* the *ndu trial* engineer c trib-tes to th o r all goals f the o ganization he s rves See I DUSTRIAL CO TROL METHODS EN GINEERING PLANT FACILITIES PRODUCTION EN GINEERING QUALITY CO TROL [R M B A]

Industrial meteorology

The omme cial appl cati f weather forma tion to th ope at nal p obl m f busines *in* d stry tran p rtat on and a r ulture in a manne int nded to opt mi e th p t with r pect t th w ther f tor Th weath r format on may cons t *of* p t w ath r re rd contemp ry we ther d t pred tion of nt pat d weather c ditions r a d tandi g of phy ical proc es e wh ch c ur in th atmosph e Th p ra tional p blems ar ba cally deci ns ega d ng cou e of t on n wh ch s me lem nt f the weath r ts an nfluence

Beca e meteorological dat a e n t a a l ble to pec fy a t p esent nd l t r st te of the atmosph r w th abs l te p i i n d knowl dge f phys al p ce es n th atm phere is compl te th appl cat on of w th inf rmat t pe t nal d c i s is properly ewed a pecial ed c f d on m k ng in th f of unc ta nty Wh t i i l ed h s be t llus-t ated by a sp fic ample d sc ed by J C Th mp in 19 0 A hyp th t cal on truct

velopment of budget segments. A budget must originate with the individual supervisor who is responsible for controlling expenditures at a particular level. Thus a plant operating budget reflecting forward estimates of departmental costs and expenses must stem from the department manager or foreman. Guidance is furnished by management, but the frequently used procedure wherein budgets are created and imposed from above falls short of its prime purpose to achieve effective control.

Budgets in their form and content are normally designed to follow the accounting classifications in use for accurate comparisons to actual performance.

An over-all budget for a divisionalized multiplant manufacturing company will consist of many segments derived from many sources within the business, culminating in final budgeted income and balance sheet statements comparable to those normally supplied to top management.

An integrated budget control includes objectives as formal statements of planned goals for one- and five-year or longer forward periods; budgets in the form of statements of proposed income and expenses and financial condition detailed by months for a one-year forward period and in more general form for the longer period, all designed to achieve the stated objectives; and performance reports that compare actual results with budget figures, together with explanations of variances.

Detailed budgets at the operating levels and the integration of these with high-level objectives and over-all budget program provide essential techniques for sound top-management action. *See* INDUSTRIAL ENGINEERING. [J.P.R.]

Industrial engineering

As defined by the American Institute of Industrial Engineers, "Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems." Industrial engineering applications are to be found in offices, stores, hospitals, restaurants, hotels, and on farms. Most industrial engineering activities are in manufacturing concerns.

Functions of industrial engineering Two major functions of the industrial engineering department are analysis and improvement of methods and the measurement and reduction of cost.

Methods improvement The most economical method of performing an activity is developed and standardized. Then the operator is trained to perform the job in the specified method. Finally the work is measured and a time standard established. The process of making a part or doing a piece of work is studied before a specific operation is analyzed. When warranted, a study of worker motion may be made to find the best manual method of performing the task. A study of systems and procedures, layout of equipment, method of handling material, and flow of work are often part of such methods improvement.

Traditionally an operator, his methods, and the equipment he uses were studied after a product had been designed and put into production. Today the economy of manufacture is being considered in the early stages of the design of a product and the development of its manufacturing method. Design of a product can materially affect the number of parts the product will have and the number and kind of operations required to manufacture it. Although motion and time study of work already in production produces large annual savings, even greater savings are possible by bringing the industrial engineer into the picture at the outset.

Some companies have methods laboratories in which experimental production lines and work-place mockups are constructed and tested. The full force of design engineer, product designer, industrial engineer, and manufacturing group is brought to bear on each aspect of designing a product for greatest economy of manufacture as well as for appearance, safety of operation, serviceability, and function.

Work measurement and labor cost control Time study and administration of wage incentives for direct factory labor were originally the main functions of the industrial engineer; work measurement and labor cost control are still his major activities. To control labor costs fully it is necessary to establish time standards for each factory operation and then, through records of output, determine how well each worker performs against the standard. Such a performance index may be determined for each worker by the day or by the week. In many plants the worker is paid a wage incentive based upon his performance (*see* WAGE INCENTIVES). The establishment of a labor standard is a major responsibility and one that only a competent and well-trained person can perform satisfactorily.

There are four methods for measuring work which are acceptable as the basis for wage incentives. The object of work measurement is to determine the time that a qualified operator should take to perform a task when working at a normal pace. This time standard, when converted into money value as it sometimes is, is called a piece rate. In other cases the standard time value is used as the basis for an incentive wage payment plan.

Time study Although time study data may be obtained by a motion picture camera, machine using moving tape, or a dial, or an electronic timer, the decimal minute stopwatch is most frequently used as the measuring device.

Elemental data In departments or plants where similar but not identical operations are performed, work elements are defined and time values assigned to each. The elemental time values are established by time study or from motion time data.

Predetermined motion time data All manual work can be divided into fundamental hand motions and mo-

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MICROBI LOGY ST I TE TILE

Food technology This i v l es the u e and con
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Th c nt ol f unwanted micr organi ms i f gr at
imp rtance a well See FOOD ENGINEERI G FOOD
MICROBIOLOGY

Utilization of wastes and surpluses The di
p al of wa te and rplu e is a ital pr blem
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S BIOASSAY e l AMI O ACIDS ANTIBIOTIC
VITAMIN

Types of fermentation F rme tat ns a de-
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m t r als wh n gr wn t g th n one way r a
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Other uses Th fi ld of num l f ed uppl
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t f gr wth stim l t s *growth inhibitor* a d
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th a t m kets a ilabl th product on f mate-
al f n the agricult r l i du t y both an

company was confronted daily with the deci ion whether to pour concrete If the concrete were poured and 0 15 in or more of rain fell in the sub equent 36 hour damage of $5 000 would result The co t of protecting the newly poured concrete from rain would be $400 To minimize the total expen e of a eries of uch repetitive decisions (optimization of the operation) it follows from the principle of the calculated ri k that protective mea ures hould be taken only when $P > C/L$ where P is the probability of 0 15 in or more of rain within 36 hour C is the cost of protective measures ($400) and L is the contingent lo s ($5 000) For thi particular ca e under the actual weather occurring during a ea on s operation the total expen e (co t plus lo s) would turn out to be $85 000 if protective mea ure were taken $72 800 if protective measures were taken e ery day re gardles of anticipated weather $32 600 if protec tive measures were taken only on days when there was a 50 50 chance of this amount of rain and $24 400 if protective measures were taken only on day when the probability of the critical amount of rainfall exceeded 0 08 that is in ratio of $400 $5 000

This approach can be generalized to include more complex decisions and relations have been de veloped by J C Thomp on and C W Brier (1955) to mea ure the e onomic utility of weather informa tion In practice le formal meth d are fre quently u d and the fundamental principle de cril ed here is handled in a qualitati e manner l y clo e collaboration l etween the meteorologi t and the u er of weather information

The sul tantial economic significance of weather in prol lems of bu ine s and indu try ha l een emphasized by a urvey conducted by the U S Weather Bureau in which an attempt wa made to assign monetary values to the aving or profits realized through applications of daily weather re port f reca t torm warnings and pa t weather record The order of magnitude of the total for the United State was $1 000 000 000 annually

S me mea ure of the economic toll of severe or unu ual weather condition is pro ided by data a eml led l y the National Board of Fire Un lerwriter which indicated that claim totalling $866 000 000 were paid a a result of 72 major hurricane tor nadoe wind torm hail torm an l rain t rm during the peri d from 1949 to 19 7 inclu i e The lo e repre ent in urance l) e not total property damage and include only in tance in which claims within in a single state exceeded $1 000 000

The econ mic l eneft that c uld l e achieve l in a single indu try the petroleum indu try l y nly a m de t impro ement in foreca t of anti ipated a erage temperatu re con liti n 1 m nth in a lvance have been analyzed with the re ilt tl at p t ntial reducti n in tankage and inventory co t has l e n con ervati ely e timated to l e approximately $100 000 000 per year These saving would be realized by improvements in heating oil cheduling made po sible through better estimate of expected space heating requirements availal le from foreca t of anticipated temperature conditions

As a result of the economic ignificance of the weather factor in a variety of indu trial applica tions there exi ts in meteorology a pecialized activity on the part of profe ional meteorologi t to erve the pecific needs which lie out ide the general public re pon il ilities of the U S Weather Bureau Thi ervice is provided either l y taff meteorologi ts employed by particular companies or by consultant meteorologi ts who work f r everal client Approximately 9% of the more than 7 000 profe sional meteorol gi ts in the United States are engaged in ome facet of indus trial meteorology A ub tantial number of these are employed by commercial airlines where the need for specialized weather information is vital for afe and efficient operations (*see* AERONAUTICAL METE OROLOGY) Ga and electric utility load e timates highway and street maintenance outdoor con truc tion work marine tran portation retail merchan dizing and advertizing flood control de ign air pollution l uilding and plant de ign atmo pheri *corro i n agricultural planning and producti n* cheduling and air conditioning and heating de ign are but a few of the activities in which the indu trial meteorol gi t has found a demand for hi ervice

Annual conference on indu trial meteorol gy are spon ored l y the Committee on Indu trial Meteorology of the American Meteorological Soci ety That ociety ha e tal li hed a program f r the certification of c nsulting meteorologi ts who meet rigorous standards of knowledge experience and adherence to high standard of ethi al practice

[T F M]

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Industrial microbiology

The tudy utilization an l ontr l of tl micro organi m capal le of e onomically pr ducing de siral le sul tan e or cl ang in t l tan

Industrial fermentation criteria Mi r organ i m t l e *indu trially imp rtant l ll have cer* tain o it tanding chara teri ti They h ul l be al le t gr w rapidly n l a a ailal le l trate and to be ultivated ea ily in la g antitie They hould l e al le t carry ut tl r ir l tran f rma tion un l r comparat ely ml n l w rkal le modif c ti n of envir nm ntal nditi n Th y l uld maintain l y iol gi al c n t n y un l r tl c n litions and r l ire e n mi ally a le qi at yield Abo e all tl mi r l i l gi l method

types a d gasoline and d e el engines Liquid pe troleum ga h s recently been introduced a a f el in thi field C n e o k t re a ailable for exist ing equ pment and some manufa tu ers offer tru ks so-powered a orig al equ pment D rect current r qu red f r charg ng storag batt i s s pro ided by motor g n r t sets o by metal di k r vacuum t be rectifiers (see STORAGE BATTERY)

El t c trucks predom ate fo operat o s in co fi ed locat o a d wh re food tuffs might be co tam n ted by exhau t f mes On open load ng platf rm and in ya ds inte nal comb ti n e gi es e empl yed for power g ndu t i l trucks

Pow ed no l ft platf rm trucks with straight and d p f ame ha long bee stand rd handli g

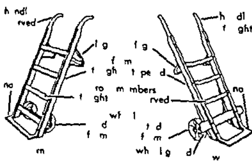
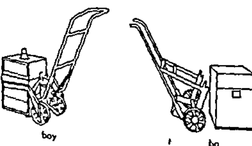


Fig 1 Tw b c typ f tw -whe l h d t k



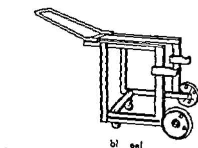


Fig 2 Low l ft h d tru k



Fig 3 P w d l ft pl tf m t ks.

equ pment Relati ely new are per nnel and bur den carriers for transporting me sengers watchmen ma l blueprints as well as material between l uild ings and in plant areas cover ng con iderable ground Shop tra tors are u ed exten i ely for mi cellaneous tow ng jobs in plant and warel ou es (Fig 3) An electr nically ontrolled tract r was introduced recently it i d rected by radio or l y wi es whicl are o erhead or c ncealed in the floor

Unit load principle The un t load principle f m terial ha dling underlies the skid platform an l the pallet f rklift method of operati n Both meth od mo e especi lly the latt r ha e revol it onized h ndl ng tech iques handling equipment and e en p oducti n of equipment so that they too can ac c mmodate un t loads

A unit load is not nece arily comp sed of arti cles which are trapped glued or oth rwi e uni t zed by means f binding mater al It can be m d p of any a o tment of article wh ch ar ac umulated and then handled with ut breaking b lk (Fig 4) Loads of this type w re developed or g nally to be arried on skids or pallet but the trend is to mak them up s that they can b han dled by sp c al devices which lim nate the n ed for any acc sory upporti g equipment The unit load p c ple has been extended as evidenced by the increas ng use of larger c nt iners and o e the-ro d tru k and trailers which are treated a u t l ad n piggy back rail nd mari e hip p ng

Skids are co st ucted in three ba ic types (1) li sk ds with fixed and swi el caste s which are too li ely fo t e ng purpo es (2) emili e skids with two fixed l gs at the front and a pair of rigid ca te s t the e r and made m b l by me ns of a jack a d (3) dead sk ds ha ing e ther two olid runners r fou m tal l gs (Fig 5) All wooden de d sk ds and those mad of hardwood platforms with metal edges nd metal legs are co vent nal others re made f metal such s ste l or l minum nd ha e sp ci l superstructure

Pallets d ffe from k d i h i g two de k r fa es separated by two or more lengthwise membe c ll d str nge whi h in s me c nstructions are placed by blocks The N tion l Wooden Pallet Manufactu e As oc at on has prepa ed and is u d sp c fi ati n for l mber f t ners and oth r p llet mpone ts D ff ent constr ction a e c lled by de pti e n mes (Fig 6) For ex mple thos w th double w ngs to perm t the use of l ng bars are the tevedore typ The two mo t c mm nly u ed zes of pallets are 30 by 40 n d 40 by 48 in B th can b carried ad a tageou ly er th ad t u ks and t a l s a d n box a d r l g at d cars The U.S Navy has standardized th latt

If a pall t is to be u ed with a low l ft truck the bott n deckbo rd mu t be o spaced that op i gs r l ft near both end so that the rollers in the f rk arm of the truck c n d op to the floor when th p ll t i b ng elevated Pall ts so c n tructed a e c ll d no re ible pallets (F g 6)

mal and plant, is receiving increased attention and will probably equal or surpass production for human consumption and therapy as well as the production of industrial chemicals. See DISTILLED SPIRITS; FERMENTATION; ITACONIC ACID; ITATARTARIC ACID; KOJIC ACID; MALT BEVERAGE; PETROLEUM MICROBIOLOGY; YEAST; YEAST, INDUSTRIAL. [R.H.H.]

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Industrial trucks

Manually propelled or powered carriers for transporting materials over level or slightly inclined or declined running surfaces. Some industrial trucks can lift and lower their loads, and others can also tier them. In any event, all such trucks maintain contact with the running surface over which they operate and, except when towed by a chain conveyor, follow variable paths of travel as distinct from conveying machines or monorails (see MATERIALS HANDLING MACHINES).

Running gear. The means employed to support a truck and its load *and to provide rolling friction contact with the running surface is the running gear.* Factors in the selection of running gear include load capacity, operating conditions, travel surface, kind of material to be handled, protection of load and machine, economy, and, in the case of hand trucks, ease of manipulation and reduction of operator fatigue.

Rollers used in dollies are of solid or tubular steel, with antifriction bearings. Rigid and swivel casters are used with dollies and with hand and powered trucks. Swivels differ from rigid types in having offset wheels and special thrust and other bearings to facilitate turning. Steel, solid rubber, semipneumatic, and other wheels fitted with plain or antifriction bearings are designed to meet specific requirements. Industrial wheels for heavy duty and special automotive type wheels in a wide selection of tire treads are used with powered trucks and tractors.

Hand trucks. Many industrial trucks are hand propelled by pushing or pulling. Some can be attached to a chain conveyor. Others are trailers equipped with couplings and can be hauled singly or in trains, as described below. Basic types and their distinctive features are shown in the table. Two-wheel hand trucks are classified broadly as eastern and western (Fig. 1). Multiwheel hand trucks are produced in many models, but platform *types continue to be the most widely used in industry* and distribution. Stakes, end and side gates, solid panels, and other superstructures add versatility to the basic machines. Low-lift types elevate their loads sufficiently to clear the running surface *(Fig. 2).*

Powered trucks. Development of compact, high-capacity storage batteries and small internal-combustion engines made possible self-powered industrial trucks. They have been responsible for extending the scope and increasing the efficiency of materials handling operations. Sources of power include storage batteries, lead acid and nickel-iron alkali,

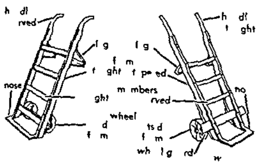
Basic types of industrial hand trucks

Type	Description	Capacity	Range
Pry	Lever bars with long, wooden handles, short steel noses and two wheels at the fulcrum. Used singly or in pairs for moving and spotting crates and similar heavy articles, as in freight cars	Up to [illegible]000 lb each	Very short distances
Dolly	Low platforms, or specially shaped carriers, mounted on rollers or combinations of fixed and swivel casters. Designated as furniture, milk can, paper roll, and so on, to indicate intended uses	From few pounds up to 80 tons for moving machinery	A few feet
2-Wheel truck	Normally constructed of wood and steel but [illegible] in aluminum and magnesium. Steel or hardwood warehouse models for general purposes, but many special-purpose types [illegible] for eggs, cartons, drums, or paper rolls	Normally 400–[illegible] lb [illegible] [illegible] up to 1,000 lb	Up to 1,0[illegible] ft
Multiwheel platform	Trucks with flat platforms mounted on various combinations of 3 (uncommon), 4, or 6 rigid and swivel casters. Addition of stakes, side and end gates, solid panels, and other accessories increases the versatility of these trucks	Normally 1,[illegible]00–[illegible]000 lb for [illegible] [illegible]	Weight is an important factor, but normally within a few hundred feet
Special	A wide variety of trucks with special superstructures and running gear. Examples include frames for glass and sheet metal, frames for plate glass, [illegible] for small parts, and trucks shaped to accommodate bar stock, textile beams, and stock items	Same as multiwheel platform	Same as multiwheel platform

types and gasoline and d sel e gines Liqu d pe tr leum ga h ece tly been ı troduc d a f l in th s fi ld Con ers n kits are a ailable f r exı t ing equ pm nt, and some ma ufactu ers offer trucks so-pow red a or g nal q ıpm nt D rect c rrent r q d for harging t rage batte ıes pr ded by m t r gene ator ets r by metal d k acuum tube rect fi r (s e STORAGE BATTERY)

Elect c trucks pr d m nate f r op r t on ın nfi ed locatı n and wl r f od tuffs m ght be ntamı ted by e h ust fumes On pen l adıng platf rm a d ın ya d ı ternal-combustion eng ne re empl yed f r powe ı g nd t ı l tru ks

P w red n nlift pl tform trucks w th tra ght and d p fr mes ha e lo g been standard h ndl n



Fg 1 Tw b typ s of tw wh l h d tru ks

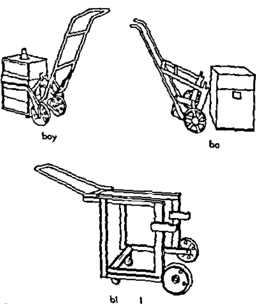
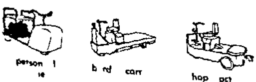


Fig 2 L w-l ft h d tru k



F g 3 P w d l ft pl tf rm tru k

equipment Relat ely ew are per nnel and l ur d n arrı rs for transporting messeng rs watchmen mail blueprints as well as materı l between build ings nd ın pl nt areas covering considerable gr und Shop t a t rs are u ed ext n ı ely for mis-ell neous tow ng j b ın plants and warehou e (F g 3) An el ctronically controlled tractor was ntroduced recently ıt ıs d rected by radı or by wires which are o erhead o concealed ın the floor

Unit load principle The u t l ad principle of material handl ng underlies the skid platf rm and the p llet forklift methods of operation Both meth od mo e e pec ally tl e latter have rev lut onized handl n te hniqu handl ng equipment and e en p odu t on f equ pment o that they too can ac c mmodate unit loads

A un t load ıs not neces arily composed of artı cles wh h are strapped glued r otherwı e unı tized by me ns f b nding mater als It ca l made up f any a s rtment of a ticle which re a c m l ted and then handled without br aking bulk (Fig 4) Load f th s type were developed orig ally to b car ıed n skids or pallet but the tre d s to m ke them up so that they c n be han dled by special de ıces which elım nat the need fo a y a essory supporting equipm nt. The *nit l ad* prı ciple h s been extended as evide ced by th ıncreası g e f la ger containers and e the ad trucks and traıle s which are treated a n t lo d ın p ggy ba k r ıl and mar ne h p-p ng

Skids a e c n tructed three b sic types (1) l e skid w th f ed and swivel casters wh ch re t l vely f r tı ring pu po (2) s mıl e *kids with two fixed l* gs at the front and a pair of rıg d ca ter at the re r and m de m b le by means f a ja k a d (3) dead k ds hav ng e th two s l d runn rs r f ur met l l g (Fig 5) All wooden d ad k ds and th e made of hardwood platform w th met l edges and metal legs r c n e t onal other ar m de of m tal ch s steel o lum n m a d hav special up rstru ture

P llet d ffer f om skids n h ı g two decks o fa es epa ted by tw r m re le gthw s members alled tr ng whı h ın s me c n tru t ons are epl d by block *The* Nation l Wooden Pallet M nufa t re s As oc at on h s p ep ed and ı ued p fi t n f r l mber fa t ners, and ther p llet omp nents D ffe nt co tru tıo a called by d s rıptı e am (Fig 6) F r xample thos with double wı g to pe mit the u e of sl ng b rs a the stev dore *type* The two m st c mmonly u ed s zes of p ll ts are 30 by 40 ı a d 40 by 48

Botl c n be carried d ntageously ın o er the-r ad trı ks a d tr ılers nd n bo and refrigerated ca The U.S N vy h tandardized th l tter size

If p llet ıs to be ed *with* a *l* w lift truck th b tt m deckbo rd mu t be p ced that op ings r l ft n ar both e ds so that th oll r ın the f rk arms of the tru k can d p to the floo wh n th p llet b ng ele ated Pall ts so on tru ted a e called n nr v rsible pallet (Fig 6)

mal and plant is receiving increased attention and will probably equal or surpass production for human consumption and therapy as well as the production of industrial chemicals *See* DISTILLED SPIRITS FERMENTATION ITACONIC ACID ITATARTARIC ACID KOJIC ACID MALT BEVERAGE PETROLEUM MICROBIOLOGY YEAST YEAST INDUSTRIAL [R H H]

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Industrial trucks

Manually propelled or powered carriers for transporting materials over level or slightly inclined or declined running surfaces Some industrial trucks can lift and lower their loads and others can also tier them In any event all such trucks maintain contact with the running surface over which they operate and except when towed by a chain conveyor follow variable paths of travel as distinct from conveying machines or monorails (*see* MATERIALS HANDLING MACHINES)

Running gear The means employed to support a truck and its load and to provide rolling friction contact with the running surface is the running gear Factors in the selection of running gear include load capacity operating conditions travel surface kind of material to be handled protection of load and machine economy and in the case of hand trucks ease of manipulation and reduction of operator fatigue

Rollers used in dollies are of solid or tubular steel with antifriction bearings Rigid and swi el casters are used with dollies and with hand and powered trucks Swivels differ from rigid types in having offset wheels and special thrust and other bearings to facilitate turning Steel solid rubber semipneumatic and other wheels fitted with plain or antifriction bearings are de igned to meet specific requirements Industrial wheels for heavier duty and special automotive type wheels in a wide selection of tire treads are used with powered trucks and tractors

Hand trucks Many industrial trucks are hand propelled by pushing or pulling Some can be attached to a chain conveyor Others are trailers equipped with coupling and can be hauled ingly or in trains as described below Basic types and their distinctive features are shown in the table Two-wheel hand trucks are classified broadly as eastern and western (Fig 1) Multiwheel hand trucks are produced in many models but platform types continue to be the most widely used in industry and distribution Stakes end and side-gates solid panels and other superstructures add versatility to the basic machines Low lift types elevate their loads sufficiently to clear the running surface (Fig 2)

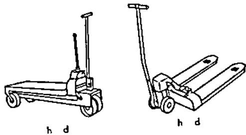
Powered trucks Development of compact high capacity storage batteries and mall internal combustion engines made possible self powered industrial trucks They have been responsible for extending the scope and increasing the efficiency of materials handling operations Sources of power include storage batteries lead acid and nickel iron alkaline

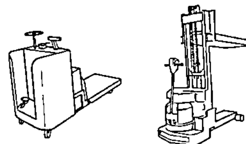
Bas c types of industrial hand trucks

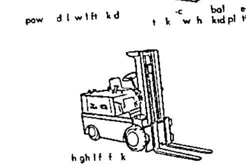
Type	Description	Capac ty	Range
Pry	Lever bars with long wooden ha idles short steel noses and two wheels at the fulcrum Used s n ly or in p irs for mo ing and spotti g crates and *similar heavy articles as in freight cars*	Up to 5000 lb each	Very short d stances
Dolly	Low platform o specially shaped c rriers mo nted on rollers or comb inations of fixed and s v l casters Designated as furn t re milk can pape roll and so on to indicate intended uses	From few pounds up to 80 tons fo moving machinery	A few feet
2 Wheel truck	Normally constructed of wood and steel b t available in aluminum and magnesium Stevedore and warehouse models a e general purpose b t m ny special purpo e types a e available for egg cr te drums or paper roll	Normally 100–500 lb but ex ep t n lly up to 1 00 lb	Up to 150 ft
Multiwheel platfo m	Trucks with flat platforms mounted on rious comb nati ns of 3 (unstable) 4 or 6 gid nd swivel casters Add ti n of stakes side- and end gates solid panels nd simil r ccess r es in cr ases the versat lity of these truck	Normally 1500 000 lb f one m n oper ti	Weight is n im portant fact r but n rmally w thin a fe h d ed feet
Spec al	A wide var ety of trucks with special superst uc tures and *running gear Ex mples ar* box fr mes for spools and sheets of metal frames f plate glass shelves for small parts a d tool shapes to accommodate b r stock text le beams nd stock items	S m as mult wheel pl tf m	Sa ult wheel pl tf

Free-l ft ı a ımp rt t fa tor ı m ope t Th ı the d t ce th ough wh h the fo ks are ele ated before the m st tart t r Where h droom ar l w a ı bo r do ble-t e ı g ı po bl f ffi ent free-l ft s pr d d

Att chm nt for e with h gh l ft tru ks ar de- gned to h dle p cifi pr du t gly o ı mul t pl un t Many ttachme t lım nate th need





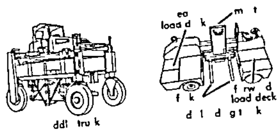


Fg 7 H d-op t d d t b l d p w d to k typ k d d p ll t t k

f a p ll t th pp t g rr f t w th d ect ec m d t g

Th ted p ty f h gh l ft f k t k b ed th w ght f th l d p d wh h th m h l ft wh th l d t l ted pec fied d t f m the t l f es f the f ks. Th l d t th t f gr ıty f f rm l d F h t k th l d t r co d ed t be 15 f t k p t 2000 lb p ty 4 f m 2000 ı 10 000 lb 36 ı f m 10 000 t 20 000 lb d d gn t d b 20 000 lb

T d f kl ft t k des g h been t w d th pl m t f f t l t hes by t q e c n rt g sol e a d d es l m h es m e c m plet p tect n f m h t f mes th gh m ff t t l yt m ffl d h g m t t t t p ov d bett b l ty



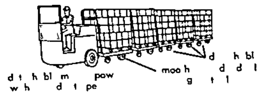
Fg 8 H vy-d ty d t l t k

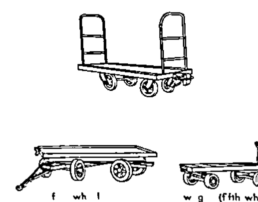
Trucks and trailers Other tru ks wh ch are cap ble f h dl g u t l ads ıncl de end l ad ng (al all d g trya d t addle c rrı r) and s de l adı g type (Fıg 8) The f rm r pıck up trans- p rt a d set down the r l d wl ı h re u u lly ca rıed n pallets r b l ter P p l mb r a d boxe f f t r typı al l ad These trucks an n t t e th r l ads that when t e ıng ı es en t al th y t am up with f rkl ft t ck I c ntrast d l d n tr cks can tr n p rt and a l tı r w thı the a h f th ı f k Further the m ch n s c n b eq pp d with cr n rms f r han dl ng l ngths f p p r lumber and w th re l c r r for payı g t able a the tr ck m es fo wa d

Tra t r tra ler r tr ckle tra s a e m t ızed s on f d tr al (na w g ge) ra lr ad b t h an ad ntag r the latter f b ng ble t foll w bl path f t a el (F g 9)

I du tr l t a t p we ed el t c lly o by ın te al-c mb t o e g es re cl fied a 3- o 4-p ı t c ntact c rd ng t the numbe of s p- portı g wh l They are u d pr m ly f erv ce l g l d g platf rm d y d operat o

Of d tr l t le s th se w th c te te r h e good t aıl b l ty (that ıs th y f ll w cl ely the





Fg 9 Eq pm t f n-pl t t t t l t kl tr

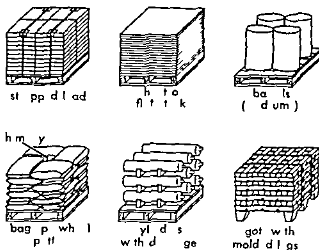


Fig 4 Loads assembled for handling a units



Fig 5 Skids for unit loads

Special pallets are those made of steel magnesium aluminum or even plastic expendable varieties (one way shippers) are made of fiberboard or light wooden elements in addition to tho e with custom made uper tructures there are elf supporting types for handling crushal le loads

Structural differences between skids (Fig 5) with consideral le clearance underneath and pallets (Fig 6) with stringers and bottom boards presenting ol tructions account for the use of platforms with the former and of nece sity fork equipped machines with the latter The double deck feature of pallets makes them more suitable for multiple tiering than the runners or legs of skids which may damage the supporting surface of the lower load

Low and high lift trucks Skids and pallets are handled by self loading machines These lift trucks pick up tran port et down and in the ca e of the high lift type tier their loads without manual handling Powered models e olved from prototype hand machines and because the first of the self pr pelled machines were led by the operator they were called walkie The name persists even though most of them are now produced as rider trucks (Fig 7)

Low lift truck hand and powered lift their loads sufficiently to make them mol ile The elevating mechani m of hand types may be operated by pulling the handle down once or several time Others have a lever or pedal perated hydraulic mechani m or a powered hydraulic sy tem Ga oline and electric model are a ailal le

Noncounterbalanced high lift trucks e olved fr m hand propelled tacker Fork equipped types are known as outrigger or traddle trucks becau e of the t t port which traddle the pallet All varieties c me with fixed or tele c ping ma t The e truck are advantageous where space is at a premium For example when piling vertically from aisles the e machines operate in aisles 6 ft wide compared with 10 ft ai les required by counterbalanced trucks of equal capacity Becau e they have no counterweight these machines are lighter than the counterbalanced types and hence are a boon to handling operations in old multi tory buildings

Counterbalanced lift trucks are con tructed by extending the wheel base adding counterweight and removing the outriggers They usually have forward and backward tilting masts They are u ed where outriggers cannot function advantageously but they are longer than their noncounterbalanced cou in

Forklift trucks Conventional fork trucks are made with any desired source of power the election depending upon the service for which the truck is intended Elevation of the forks forward and backward tilt of the mast and the power for actuating attachments is provided by the hydraulic system Thi consists of a pump to draw oil from a re ervoir and force it through control valves which are manipulated by hand levers selected by the machine operator into piston actuators

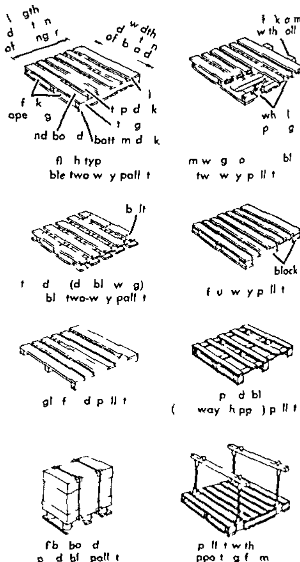


Fig 6 St d d a d pe ial pall t

Inertial guidance system

A self-cont in d v h le b rn ppa atu f r en ng cha g in th moti n f v h cl A l r met s, m nt d on a gy o tabil d pl t f rm n e rv c elerati of the eh cl a d a mp t c mpil the a ele ati n ign l t pro- du a e nt u l of eh cl p sti A f ed ba k t hn que k w a S h le tun b u d ertain imp tant r r nd g eatly impr s sy tem a c r cy S e NAVIGATION SYSTEMS ELECTRONIC.

In rt l gu dan y t ms a gate automatically p loted r ft lo g r n e m le h p nd subm r e Th ep c v ges of th ubmari es N ut l a d Sk te und the p lar ic ap w r m de p bl by n rtial aut n v gat r

Principles of operation An i ert l y t m nav igate l k bl df ld d man be ng taken fo a r d h k ps t a k of ry t n and h g i pe d by f l t j dg th t t l d t nc nd d ect on h h bee t ke I e t l g da c u el r m t t en cha e motion gyro- c pes t p d d to r f e nd a p e- i on l ck fo mput ti

A mple l met hown n Fig 1 Wh n th eh l le t m m ha g ba k b cau of t tia Th e ult ng pr g omp e on wh h p p rti l to l at on i measured ele tr lly S ACCELEROMETER

Two mp t l m nt k wn a teer t r obta n h le po t o f om le at on by m as u g t me-pl t a s n F 2

F a g ti n o e fl t ea th tw ho iz tal le t te s w ld be m nted p p di la t a h th o pl tf rm a n F g 3a a d m po t nd y f eh le p st n e mput d i

Fig 1 El m t ry l m t

Fig 2 I g atio f a t t g l ty d in eg io f locity g ve d st

Fig 3 N g t on fl t rth ( ) G m try (b) C mput

Fi 3b Tl e pl tf m s dir cti nally tabilized by gyro c p

A tual navigat on o e the urved earth i de picted i F g 4a B th azimuth angl nd platf rm t lt m st be ontr ll d be au as the eh cle m ve thr ugh d tanc tl ac eler mete mu t be r tat d about h zontal a is th ough angle $\Phi = x/R$ whe e R is th e rth dius to keep them locally le l they w ll not en e gr ity Th a ompl hed by ng m a red veloc ty $\dot{x}$ to dr e the ac ele or te platform always t th r te $\dot{\Phi} = \dot{x}/R$ hown in Fig 4b If the e a e no e r tl e acc le meters main h ri ont l d pit m u e f th v h cl

The a celeromete platform is dr n f om an th r pl tf n called a tabl pl tf rm wh ch i held g l ly fixed in p e (w th gr at p eci n) by gyr p c tr ll g all thre a e The t ble pl tf m s g mb l upp rted to be ng la ly nd pende t f th vehi le (GYROSCOPE) In Fig 4 locity h s b en tegrated g metric lly nd n at o al p t on a labl a platform ngle Φ o th t the t ble platf m has r placed tl e fixed t rs f el tial n gat o

Schuler pendulum The t m of F g 4 a ts a pe d lum be a if (while in a t ti nary lo ati) th platf rm s tilted l ghtly off lev l a p op t o l g v ty force acting th ugh the ac c l m ter w ll dri e it back t w d le el The t m w ll o e hoot a d o cillate defi t ly with a p od

$$T = 2\sqrt{R/g}$$

wh h g th ac le at n d t gra ity of f ll g body o the arth su fa e T s b ut 84 m

Th b hav r d nti al to th t f simple p d l m ha ng a l gth eq al to th ad us of th e rth The tem i ll d Schuler p ndulum s a d to b Sch ler t d fte M Schuler wh h w d 1923 th t ny pendulous d ice w th th p r d w ll mai l c lly rtic l de p i m m nt f its p nt of s pport S e SCHULER PENDULUM

path established by the tractor) those with 4-wheel steer are rated as having excellent trailability but are difficult to maneuver manually and those with fifth wheel (wagon) steering are effective with heavy loads They are offered in a wide variety of constructions which makes it possible to select one with proper characteristics to meet given require ments

Each type of industrial truck is used to the best advantage when carrying the particular load for which it is intended Several types may be found working singly or as teams For example palletized loads may be transported on tractor trailer trains and then distributed and tiered by forklift trucks [D O H]

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Inert gases

The inert gases listed in the table constitute group 0 of the periodic table of the elements They are also called the noble or the rare gases although argon is not actually rare and helium is not rare in the United States

All these ga es occur to some extent in the earth s atmosphere but the concentrations of all but argon are exceedingly low Argon is plentiful constituting almost 1% of the air

All isotopes of radon are radioactive the longest lived having a half life of about 4 days Ea h of the other inert gases has at least two table (nonradio active) isotopes in addition to one or more radio active isotopes

All the gases are colorless odorless and taste le s They are all slightly soluble in water the solubility increasing with increasing molecular weight They can be liquefied at low temperatures the boiling point being proportional to the atomic weight All but helium can be solidified by reducing the temperature sufficiently and helium can be so lidified at about 1 K by applying an external pres ure of 25 atm or more

The atoms of the inert gases are characterized by the fact that in each of them the outer shell of electrons is filled Therefore none of the e atoms forms chemical compounds in the ordinary sense of the word although they do form some weakly bonded clathrates and a few unstable diatomic

The inert gases

Name	Symbol	At m numbe	At w ght
H l um	He		4 003
Neon	Ne	10	0 183
Argon	Ar	18	39 944
K ypt n	Kr	36	83 80
Xen n	Xe	54	131 30
R d	Rn	86	2

molecules and ions Under ordinary conditions molecule of the inert ga es are monatomic

All the inert gases except helium and radon produced in concentrated form by the liquefact and distillation of air followed by special purifi tion proces e Helium is obtained from cert natural ga es containing 1% or more helium R don is obtained by collecting the ga called dium emanation given off in the radioactive dec of radium *See* ARGON ATMOSPHERIC GASE PR DUCTION OF HELIUM KRYPTON NEON PERIOD TABLE RADON XENON [C A C

Inertia

That property of matter which manife ts it elf as resistance to any change in the motion of a bod Thus when no external force is acting a body rest remains at re t and a body in motion continue moving in a straight line with a uniform pee (Newton s first law of motion) The mas of a bod is a measure of its inertia *See* MASS [L N

Inertia of energy

The principle of inertia of energy state that th inertial properties of matter determine and are de termined by its total energy content If E is the to tal energy content and m_0 the re t ma s of a piece of matter c being the speed of light the mas en ergy relation is $E = m_0c^2$ This formula was pro posed on general grounds by H Poincare in 1900 and was deduced from the special theory of relativ ity by Albert Einstein in 1905

If the mass of a body changes by an amount Δm the corresponding energy change is $\Delta E =$ c Δm The existence of disintegration proce s in atomic nuclei has made it po sible to te t this formula with great accuracy Energy relea ed from nuclear reactions provides the power ource in nu clear reactors as well as the principal energy source in the sun and other stars The radiation emitted from the sun is equivalent to a lo s of ma s of about 4 000 000 tons/sec

The statement that the re t ma s of matter is de termined by its total energy content is not u cep tible of a simple test since there exists no inde pendent measure of the latter quantity The validity of the general principle was adopted by Einstein as a cornerstone of his theory of gravitation Ac cording to this theory the gra itional proj ertie of matter are determined l y the di tribution of en ergy in the univer e Matter and energy are u ed as interchangeal le term all (rm of energy l eing sul ject to grav tational action Phy ical predictions made by Ein tein on the ba is of thi principle are (1) light passing near a star hould l e deviated l y the gravitational field of th tar and (2) l ght emitted from a ma ive star ho ild lo e energy in e caping from the star and c n equently should ap pear to be lightly reddened with respect to a ter restrial ource (gravitational red shift) B th the e effects have been sul jected repeatedly t physical test results favor Ein tein s pre lictions *See* EIN STEIN SHIFT MASS RELATIVITY [F L H]

Infant diarrhea

A mp rt t ymptom p rp sely d u d s a a ut pec fi d a e n med l l ter ture Babi c mm ly exhib t d r h b t e t n flu d nd blood h m ll c n be fatal T atme t t ses co t l f these l es with pla eme t wh l th ca e of th d rrhe ght Sto l a n me o r at ry gr a d o ta mu u Blood p g e t p fi nt r t h as b ter l r ameb c dy e t y D rh a ft n de t nf ct o Th e ev d tl t ru ı al o au at a d th t n rm l t tı l b te an be ome p tho- ge c d a e-p d cı g unde c t o dı t Othe r cl d food e t ty r ll gy nd food p g u h by o t m at d m lk Ep dem c d rh a f the wb th descript term f a er u ıt at the m l dy wh h w desp e d h p tal nu r S AM EBI IS B CILLARY DYSENTERY BACTERI LOGY ME ICAL FOOD OISO I G BACTERIAL VIR LL NCE VIRUS [P L B]

Infarction

A pr s f lar b t ctı e lt g a r g of cr c ll d ınfa ct Th u l se oc lu of art ry e by a thr m b mbol th d l pme t depe d t gr t t t n the ll t al c l t n If the a to- m tic blood pply ı d qu t f th el ı th l urc f bl od pply t th reg n ı f ct res lt

F ll w g a tal p riod f hyp em the ı f r t d g bec me pale B a e f the b h g g me t f the l y t m f t f the ple k d y d l g re lly wedg h p d w th th b f th w dg t the pe ph ry a d the pex t w d the point f as l b tru t S E BOLUS THROM o s

W th oc l f an artery th t g collat r l l t w ll ıt mpt t brı g m blood t th eg D pend g th e t t f thi p c es the f ted w ll b ed p l Th p oces w th th o ga ı l d Tho f

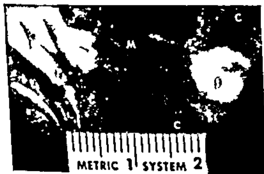
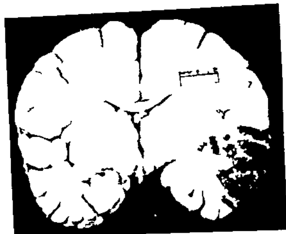
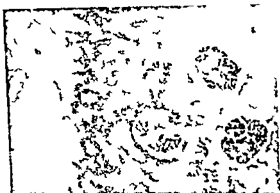


Fig 1 M g fi d gro ph tog ph f w dge-sh ped f rct f th kid y (I) Th l rt (C) med ll ry py mid (M) d l p l (P) b l ly se



Fg 2 G ph tog ph of a sect of b h w g w dge-sh p d f t Th lt d f om a th mb f th b h f th m ddl e- b l rt ry Se d ry h m rrh g h o rr d l t th f ct d t (I)



Fg 3 L w p w w f th dg f l f ct Th m t f gl m l d th gh t f th d d l t b l t ll b se i th f rct d g (I) O th l ft l l t ly b tt pe- rv d gl m rul d t b l l b A f fl mm t ry ll (C) p t g th d d d l t ly b tt p rv d t

th k d y nd he rt e p le wh e tho e f the pl d l ng u lly r d With de th f the tı s th eg d d l t t n f th nearby l a dary h m rrhag m y occur

Th t th ffected ea u d rg c ag l t ec o d d es Th tı d th ı f cted g b m ı flamed Soon fib obl t t ty d g nizat n b gı E t ally th d ad t r pl d by hru k dep es ed

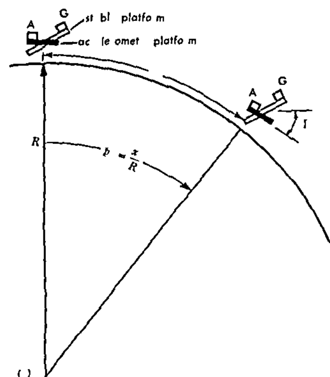
I f r t c mm ly o ur n the l g h rt br spl en, d k d y The mm n ca e f f t f the h rt s th ombo of th co n ry t ry s ally sec d ry t rteri scler ı

I f r t f p rt f b w l w ll es lt ın d th f th ı d ıd l nl s g c l t rv nt n s f th m g As m ght b a med beca se f th f q y f th mb the ı d right u

The curved earth Schuler tuned system (Fig 4) produces accurate navigation for trips lasting many hours or days while the flat system (Fig 3) becomes inaccurate in a short time

Navigation errors Suppose for example that an accelerometer is in error by a constant value of one ten thousandth of g so that ϵ = 00322 ft/sec In Fig 3 the integrators turn continuously and the distance error grows as ϵt /2 so that after 1 hour the error (Fig 5a) is 4 miles and after 2 hours it is 16 miles In Fig 4 the output of the integrator begins immediately to tilt the platform in a corrective direction and the final platform motion is an oscillation (Fig 5a) about a position one tenth of a milliradian (006) from the true vertical with a resulting distance error between 0 and 0 8 mile after any length of time

A drifting gyroscope tilts the stable platform at a constant rate and produces an error (Fig 5b) growing as t^3 for flat navigation (Fig 3) but growing only as t (on the average) for the Schuler tuned system (Fig 4) Thus after 1 hour a gyro drift of ⅛ /day (one ten thousandth of the earth s rate of spin) produces errors of 20 miles for flat navigation but only 1 mile for the Schuler tuned system For long term navigation the statistical character of gyro drift actually leads to a position error growing approximately as the square root of t



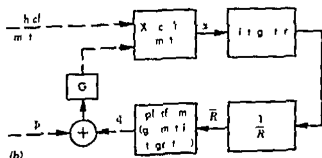
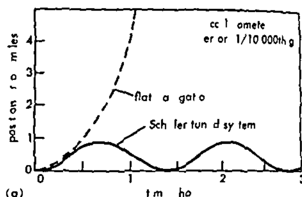


Fig 4 Schuler tuned system (a) Geometry on spherical earth (b) Computer configuration



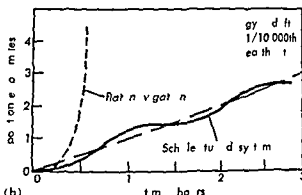


Fig 5 Inertial navigation errors arising from (a) accelerometer error (b) gyro drift

Errors in the navigation computer produce additional positional errors Computer errors arise out of the complexities of unscrambling the mathematics of acceleration in spherical coordinates on a rotating earth and of accounting for the earth s slight nonsphericity and other geodetic and gravitational variations See EARTH GEODESY

Initial misalignment also produces an 84-min oscillation Alignment may be performed optically using a known reference or by the gyrocompassing technique whereby the system is allowed to seek gravity (leveling) and the direction of the earth s spin axis

Aided inertial systems When means are available the accuracy of an inertial system may be improved in two ways (1) by check point corrections and (2) by auxiliary velocity correction

Check points may be introduced by discrete resetting or continuous monitoring using radio radar or automatic star tracking equipment

Independent velocity data may be obtained from Pitot tube or Doppler radar and serve to damp the 84-min oscillation This method requires caution however because errors in velocity data produce navigation error [R H C]

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Infant diarrhea

An mp rta t ympt m pu p sely d c ed as n ute pecifi d ea n m d al lit rat r Bab e comm ly e h b t d hea b text i e flu d a d blood chemic l l s an be fat l Tr tment t s o tr l f these l s w th repla m nt wh le the e f the d a he s o ht Stool a num r u o w tery g e a d c ta muc s Blo d pu ugg ts pecific t rit u h s ba t rial o ameb dy ent ry D rrhe ft n de tes i f ct n The i ev d n e tl at i al c at e d th t rm l ntest l bact ria can bec m patho- g d e prod ing u de ert n ond ti Othe r a s cl d f d en t ity o ll rgy and food p i nt g uch by nt m ated m lk Ep dem d a h a f th n wbor the d c pt e term f r e t ti n th m lady wh l wid p ead h p tal n r e e S e AMEBI S S BACILLARY DYSE TERY BACTERI OLOGY MEDICAL FOOD POISO I G BACTERIAL VIR ULE C VIRUS [P L B]

Infarction

A proc s f cul ob truct r sulti g in reg o f ec i ll d a nf t Th u l l on f rt y o b a th m b s mbolus th d lopme t d pend t a gr t exte t on th ll te l ci c l t n If th sto- m ti blood pply i ad q t f the es l the f s of blood pply t the gio f t e lt

F ll w g t l p iod f hype mi th i fa ted reg n bec m s pale Bec u e of th b a h g a ng m t of the ula y tem f t of th pl k d ey and l g a e u lly edge- h ped w th th b f th w dge at th p phery d the apex t w rd th p nt f l b t t S E IBOLLS THRO IBOSIS

W th l n f n t y th e st g ll t e al r lati n w ll attempt to b ng m bl d t th reg n. Dep nd ng n th t t f this p es the f r t d ea will be d p le Thi p ocess es w th th g l ed Th f

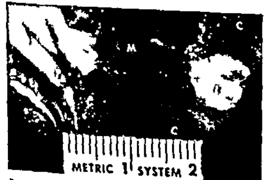


Fig 1 M g fi d g ph tog ph f w dge- h ped l f rct f th k d ey (I) Th f rt (C) med ll ry py m d (M) d l pel (P) b le ly se

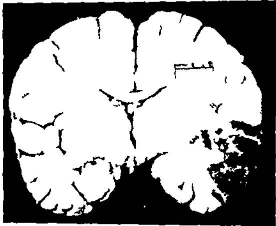


Fig 2 G ph t g oph f t f b n h w i g w dge- h p d f ct Th s lted f m th mb f the b h of th m ddl e e- b l rt ry Se d ry h m h ge h c d i t the f ct d t (I)

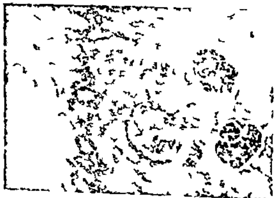


Fig 3 L w p we w f the dg f r l f ct Th m t f gl m l d th gh t f th d d l t b f st ll b th f ct d g (I) O th l ft l l t ly b tt p e- rv d gl m l d t bul l b A z e f fl mm t ry ll (C) po t g th d d d l t ly b tt p rv d t

th k d ey a d h t e pal wh eas tho e of the ple a d l re ually ed W th d th of th t u in th on nd d l tati n of the ne by el a sec d y h mor h g may o c r

The t sue in the ffect d ea u d rg c g l t o a d d s Th tis ou d the in f cted r gio b m i flamed So n fib bla t a t ity a d gan zat o b gi E e t lly th d d t ue i epl c d by sh unke d pre ed r

I f t mm nly c u n th l g heart b spl en, a d k dney The c mm u e of i fa ts f th h rt thr mbo s f th rt ry sually se d ry t a t scle s I f i n f a p rt o f bow l will result n d ath f th d id al u le s urg al i tervent n f rth m g As might b as umed beca of the f q n y of th mb i th a d ight u

ricle embolization to the lungs is a rather frequent occurrence However because of the collateral blood supply of the lungs infarction follows only when there is some interference with the circulation such as chronic pulmonary venous congestion An extensive collateral circulation also exists in the liver hence the rarity of infarcts in this organ *See* CIRCULATION DISORDERS

[R A V]

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Infection

A term considered by some to mean the entrance growth and multiplication of a microorganism (pathogen) in the body of a host resulting in the establishment of a disease process Others define infection as the presence of microorganisms in host tissues whether or not it evolve into detectable pathologic effects The host may be a bacterium plant animal or human being and the infecting agent may be viral rickettsial bacterial fungal or protozoan

A differentiation is made between infection and infestation Infestation is the invasion of a host by higher organisms such as parasitic worms *See* BACTERIOLOGY MEDICAL EPIDEMIOLOGY INFECTION LYTIC MYCOLOGY MEDICAL PARASITOLOGY MEDICAL PATHOGEN VIRUS [D N L]

Infection lytic

Infection of a bacterium by a bacteriophage with subsequent production of more phage particles and lysis or dissolution of the cell The viruses responsible are commonly called virulent phages Lytic infection is one of the two major bacteriophage bacterium relationships the other being lysogenic infection *See* BACTERIA LYSOGENIC BACTERIOPHAGE COLIPHAGE [P B C]

Infectious disease control

Since infection depends on factors in the host the parasite and the environment there are various means by which infectious disease control may be brought about Immunization strengthens the defenses of the host chemoprophylaxis is directed at the parasite and quarantine and sanitary measures remove the parasite from the environment of susceptible people

Immunization has been successful in controlling smallpox diphtheria tetanus and whooping cough and offer great promise in poliomyelitis It protects the individuals immunized and when the number so protected has reached a high enough level it may prevent the outbreak of an epidemic Chemotherapy is now used successfully in the treatment of many infectious diseases and is therefore effective in controlling the secondary spread of the diseases Chemoprophylaxis acts at an earlier stage it may be defined as the use of drugs to prevent the development of infectious diseases Persons exposed to tuberculosis for instance may take isoniazid with the objective of preventing the tubercle bacilli from becoming established

Quarantine may be defined as such a limitation of freedom of movement of persons who have been exposed to a communicable disease that for a period of time equal to the incubation period of the disease they are unable to make effective contact with persons who have not been exposed The term may also be used for less extreme degrees of isolation Quarantine has been effective in countries such as Australia which are distant from other centers of population so that people arriving by sea will have had opportunity to develop during the voyage any infectious disease they may be incubating Examination at the quarantine port will then be effective Quarantine is likely to be less useful as air travel becomes more common

The basic importance of sanitary measures in the control of infectious diseases is due to the fact that certain microorganisms that infect man are excreted in the feces by patients or carriers If sewage disposal is inadequate contamination of the water supply is likely Preventive measures are concentrated both on the safe disposal of sewage and on the provision of clean water The diseases that may be controlled by these measures include typhoid fever dysentery hookworm and infectious hepatitis *See* EPIDEMIOLOGY [C W H]

Infectious disease transmission

The transmission of infectious disease is accomplished in several ways

1 There may be direct contact with an infected person The venereal diseases are almost invariably and measles is commonly spread in this way *See* GONORRHEA LYMPHOGRANULOMA VENEREUM MEASLES YAWS

2 Certain diseases are spread by direct contact from lower animals to man an example being undulant fever which may be transmitted directly from cattle goats or swine (*see* BRUCELLOSIS) Animal ringworm is another disease in this class *See* ZOONOSES

3 Milk borne infectious diseases include typhoid fever scarlet fever summer diarrhea and bovine tuberculosis The cow infects the milk with bovine tubercle bacilli but in the other diseases listed the infection is from human sources The milk responsible is almost always raw since pasteurization properly carried out can be relied on to kill pathogenic microorganisms *See* MILK SCARLET FEVER TUBERCULOSIS TYPHOID FEVER

4 In the past there have been many serious epidemics of waterborne diseases They included epidemics of typhoid fever cholera bacillary dysentery and amebic dysentery As a result of chlorination these infections have been eliminated from

th wat upplies f la ge mmunit e i many pa t of the w ld S e WATER BORNE DISEASE.

5 Ga tr e te tt d e t th *Salmo lla* group f rgani ms s a food borne di ea e in certain in sta ces P rk and po ltry are p rt ul rly l able t b o t m ated and duck egg ha e been n c im t d on e al oc as Am h dy nt ry m be t a sm tted by o t m n ted eget ble S e SALMONELLA

6 A m l i fect o i n that s p e d n hosp tals An u ge t p blem t th p esent t me the pr ad f st phylococci many f th m anti b t c es t t i hosp t l Se STAPHYLOCOCCUS

7 Art l s wh h becom o t mi ated by n t it with a p t nt are kn wn a f mites and the e i turn m y c u f m te-born nfe t n Am g h ld e there s c derable traffic n l by m a of toys ther t m nated obj cts wh h erv me ns f nd r t nt ct betwe n a a e and a u c pt ble a soiled l thing bedd g nd d e g D e es tr m tted n thi way includ t eptoc c l fect ons nd d phth ria S DIPHTHERIA STRE OCCUS

8 Insect ve t e th m t impo t t me n f p ead g c rta d ea h a yell w feve leep ng kne plagu nd typhu Th in t l ed a e resp t ely m quitoes t et e flie fle and l e Thes i t a nfected but the h sefly may an e d a by ct n a pas i e c e l g rm a qu ed fr m nf cted mat i l h feces S P GUE SL EPI G SICKNE S AFRICA TYPHUS FEVER E DEMIC (FLEA BORNE) TYPHUS FE R E IDE IIC (LOU E BORNE)

Host parasite relationship The *t a m s* of d m also b st died as a p obl m t host pa a it el t n h p The a dynam c bala ce bet een the ffort f th pa a ite t m lt ply and th d fe f th h t ag t infect *Enviro m ntal fa t r* u h temp atur nd h m d ty m flu th q l br m between the two *pro t g n t* th f r th ee ets of fact ociated resp t ly w th the par t th h t d th r nm t e de ed

B t l p p l t The b cte i l popul ti n th r mi r p a te populat m y b fa ly r t t bi l g l effects n the h t Th ri f m les n this t g ry The v ru e f nfl za h w *n m ked* nt a t n th y h b t la g mt r f t a n wh h ary th t t e d th effects o the h t d h h p tect n n nfl za pi d m m be ly p rti lly p ot t e o n t at ll p tect n n th Th ru f A i fl nza f mpl w unl k a y th t had b n u t l er t ea th ugh th wa m d n th t ld peopl po es d *a t bod es* h t i d ted th h d e nt ed the m ru p eri l

F t h t p p l t n The g est f n p l m d pe d l f t n th h t p p l Th g d t h t mport nt bee u m ny m oo g n m a e lect n the age g up th y n k m gococ al me g t s i m e l kely t attack younger age g oup and th e have the efore been everal epidemics n army camps in wh ch nu ne ou y ung recr ts were li i g The fact r l crowding is al o imp rtant in this ca e d ts nfluence may be s en gain in the high rat fo certain d s a e in slum over cr wded ja l and mental h pital

E i r mental fact rs N imerou en ir nmental fa t r act n b th th bacterial pop lat on and the h t p pulation Pro n f cl an w t r and p ope ewage d p s l h e l e n the ch f fa tor le ding to a ed cti n f tl e ente ic di ea s in ma y c mmun ti s A res lt of o-e lled anitary reform typho d f er is now t all unknown in modern cit es

He d immu ty Wh n a ho t is infected he may r act su c f lly to the par te nd n d ng produc ant bod e th t n ke h m immun f r me t me fr m f rthe attack f the para ite A well a c ns d ng th immunity of the ind dual one may al o study h rd mmunity that i the immu n ty st tus of th p pulat n a a wh le If the *m* mun ty a quired to a part cular p ra ite i l t n th s sceptibles w ll te d to be c nc *ntrated in the* yo nger age group a d n ep d mi will mo tly in v l e th s ction l the p pulat on The c mmon l ldhood i fe ti n uct a m a le a d ch k n p x ill strat th point On the oth r hand the immu ty t nfl e za s h t l ed and thi di a atta ks all ag g ups

Th eshold d ity If th prop rt o f u pt bles bel w c rta r t cal value known as *th threshold d* n ty an i fect ntr du ed int th group w ll d ut Th s i an imp rtant fa tor n the cycl al l eha i r f epidemic Duri g th e dem c p od the de t *of* su ceptibles gr duall inc as a d the nd ti s bec m appr priate f a furthe *outbreak*

Nonhuman hosts So f r th h t u d r on ide t n ha b en the human but there a e ho t other th n m n wh ch may unde natural ond t o s h bor an nfe t is agent p th *n* for ma An ep d mi of plague in m s alway preeded by a orre p d ng outbreak n th cept bl de t *nd hen th* nfectio rate becom h gh i this h t tl e d sea spills o er t ma S EPI EMIOLOGY [C W H]

Infectious mononucleosis

A d a e f h ld a d p rt c larly of yo g dult ha teri ed by fe e and e larged lymph o d t

The ag nt pre m d but not p o en t be v l l ar vid ce of xp r me t l tr n mi on ha n t been bt ned

O et of th d ea l w a d no pecific with va i ble f er and mal e late cer ical lymph n d s nla g nd i *about 50%* of ca e th pl e l bec me l rged Th di e s la ts 4- 0 d ys o l ng r Ep dem e ommon n in t t t wh r yo g pe ple l

Fo d gn th h t phile a t body t t u f l Th t t based o nspe fic erol g

reaction present at high levels in patients with infectious mononucleosis Total white blood cell count and differential blood count are also useful in diagnosis *See* HETEROPHILE ANTIGEN [J L M]

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Infective dose 50

An important special case of the median effective dose is the dose of microorganisms required to cause infection in 50% of the experimental animals This is known as the infective dose 50 ID_{50} or the median infective dose In former times it was the practice to try to measure the least amount of infective agent that was needed to produce a definite infection but this proved to be a very variable quantity The median infective dose is a much more reproducible measure though it is still necessary to specify in detail certain conditions to be observed during the measurement of this quantity For example the median infective dose varies widely according to the route of administration a dose that is ineffective by mouth may cause a high rate of infection when given intravenously *See* EFFECTIVE DOSE 50 [C W H]

Infinity

The terms infinity and infinite have a variety of related meanings in mathematics The adjective finite means having an end so infinity may be used to refer to something having no end To be more precise the mathematical domain of discourse must be limited

Infinity in sets A simple and basic example of an infinite collection is the class of natural numbers or positive integers A fundamental property of the positive integers is that after each integer there follows a next one so that there is no last integer Now it is necessary in mathematics to treat the collection of all positive integers as an entity and this entity is the simplest infinity or infinite collection

Suppose that two collections A and B of objects can be set into one to one correspondence that is each object in A is paired with one and only one object in B and each object in B belongs to just one of these pairs Then A and B are said to contain the same number of objects or have the same cardinal number This is equivalent to the ordinary meaning of the same number obtained by counting when the collections A and B are finite and is taken as the definition of this phrase in the general case

Now let A consist of all the positive integers and let B consist of the even integers Then A and B have the same number of elements since each element of A can be paired with its double in B thus elements can be removed from an infinite collection without reducing the number of its elements This property distinguishes infinite collections from finite ones and indicates that the statement the number of elements of a collection A is greater than the number of elements of a collection B should be taken to mean B can be put into one to one correspondence with part of A but not with the whole of A

Consider next the number of subsets of a given collection A For example let $A = \{a\ b\ c\}$ that is A consists of the three letters a b and c Then the sets $\{a\}$ $\{b\}$ $\{c\}$ $\{a\ b\}$ $\{a\ c\}$ $\{b\ c\}$ are subsets of A To these for convenience can be adjoined the null set containing no elements and the set A itself This makes a total of $8 = 2^3$ subsets It is readily proved that a set A having a finite number n of elements has 2^n subsets Thus the number of subsets of a finite set is always greater than the number of elements By a different method the same property may be proved to hold also for infinite sets Hence for every infinite number there is a greater number In other words there exist infinitely many distinct infinities Sets having the same number of elements as the collection of positive integers are called countably infinite and this is the smallest infinity

Infinity in limits of functions The term infinity appears in mathematics in a different sense in connection with limits of functions For example consider the function defined by $y = 1/x$ When x tends to 0 y approaches infinity and the expression may be written

$$\lim_{x \to 0} y = \infty$$

Precisely this means that for an arbitrary number $a > 0$ there exists a number $b > 0$ such that when $0 < x < b$ then $y > a$ and when $-b < x < 0$ then $y < -a$ This example indicates that it is sometimes useful to distinguish $+\infty$ and $-\infty$ The points $+\infty$ and $-\infty$ are pictured at the two ends of the y axis a line which has no ends in the proper sense in euclidean geometry

Infinity in geometry In geometry of two or more dimensions it is sometimes said that two parallel lines meet at infinity This leads to the conception of just one point at infinity on each set of parallel lines and of a line at infinity on each set of parallel planes With such agreement parts of euclidean geometry can be discussed in the terms of projective geometry For example one may speak of the asymptotes of a hyperbola as being tangent to the curve at infinity Note that the points at infinity which are adjoined to a euclidean line or plane are chosen in a manner dictated by convenience for the theory being discussed Thus only one point at infinity is adjoined to the complex plane used for geometric representation in connection with the theory of functions of a complex variable

Other concepts Other types of infinities may be distinguished when properties other than the mere cardinal number of a set are being considered For example a line and a plane contain the same number of points but when continuity considerations are important the line is said to be made up of a single infinity of points whereas the plane has a double infinity or ∞^2 points This is because there exists a one-to-one continuous correspondence be

twee the line a d a ubset of the plane but th re does not x t such a r e ponden e I etwe n the wh le pla a d the l ne or any p rt of it As an othe example an i finit t may be ordered in d ff rent way so as to h e d ffe ent rd al n m be s. S e CALCULUS DIFFERENTIAL AND INTEGRAL. [L.M G]

B bliog aphy L. M Gra es Theo y of Fu ctions of Real I ar ables 2d ed 1956

Inflammation

A respon e f an mal t ues to n njurion stimu lu U lly the term i applied to e j n wh ch a r flected n an altered stru ture I the t ue i jured Alth ugh the mphasi i on th hang s n th nju ed focus the tatu of tl e ntire rgan i m ffects th r pon e Othe modify g ariable ncl de the agn t d durati n a d nature f tl e i jur ag nt and the sp cific s te of njury e en though the fu damental nde lyi g react ns ar th sm reg rdl s of th typ f injury

The funct n ally a cr b d to this pr ce is that f defen e aga n t inj r ous age t and s th efo e clo el ass c i d with the pr cess f repa r th t e t rati f the ltered foc s t a t t app x mating th t wl ch x ted befor the j ry Although fl mmati n and epa ar freq ently b fici l t the rgan m ca n these respo es m y b g eat as t interfe e r ou ly w th no mal f t on a d attempts m t be m de t ppres th nflamm tory r r par ti p oc

U ually i flamm i n of a part cul r t s e o g n s nd ated I the additi f iti t the w rd root for th aff cted part Thus inflammati n f th l r hepa s te med h patit d of th c l coli ti Th te m are furthe mod fied a t d at t l g cal age t cha t r as a ute ral hep t t r ch ni lc at ve c l t By common sage th t rm pn um ia i a epted f r infl mm ti of th lung p t cul rly wh n th u c t l ba ter al alth ugh pn um niti i u ed al

Acute inflammation The ca din l gn of n flamm t n in k n w r d b d by Cel s n th fir t t ry s bor (rednes) c lor (heat) t mo (swell g) a d d l r (p in) Late a fifth gn f n ti l r l f f n ti w add d b C l n These ign n be expla ed a d ampl fied by b rvat on a imal t e r i ng t n jury

Imm d t ly f ll wing njury the bl od ap lla es d l t nd add t nal ap ll ri s be om filled with blood The augmented blood fl w to the kin e lt n redness a d in ea ed he t The te l blood fl w l wed nd wh te bl od ell leukoytes, wh ch rmally r a ed n th axi of the fl wing t am ppro ch the m g n of th es el wall At th m t m th li g ndotl el um of th v s l bec m t ky and th whit blood cell imp g n the w ll th y bec me loo l at ta hed Th perm ab l ty f th cap llary w ll is alt ed th t w t and alt po r out f the es sels as edema fluid If the increa e i perm ability continu pla ma proteins and the attached white blo d cells along w th some red I lood corpu cles w ll pass into the extrava ular spaces and c m pr se an exudat The in rea e in extrava cular flu d whether edema or exudate cau welling and principally becau e of effects f pre sure on nerve e d ngs re ults in pain A the l lood flow slows and the bl d b omes more i cou becau e f lo of flu d there is an increa ed i ndency for clotting This has an effect of l elping to local ze the inflammatory agent in many ca es The harac ter of the xudate arie depend ng on the nature of the inj rio s agent When c rtain l acter a are the cau ati organi m the e udate i often puru lent that i it ntain m ny polymorphonuclear leukocytes The e cell facilitate the de truct on f the ba t ria by ngulfing them into their cytopla m a process termed phag cytosis S e PHAGOCYTOSIS

Healing This may oc ur by re olut n f the exu date if death of ti sue cells has not occur ed In thi p oce the edema fluid is rem ved by the lymphat c y t m and large mon nuclear white cell phag cyt e p rti ulate matter and tra sp rt t t adj cent lymph n d If e ten i e necro i of t ssue cell has ccurred healing must proceed eith r by the replacement of the lo t cells by re gene at n o by the dev l pme t of granulati n ti u nd ltimately the f rmation of car tis ue Gran lat on ti ue s f rmed when buds of endothel al ell gr w f om adjac nt cap llar es and fibr bla ts fr m ne rly t s e migrate into th fibr us ex d te th reby forming a network of pillari s in a loo e strom f fbrobla ts The fibr blast lay down coll gen a d th capill ri s bec me d mini h d E entually there i lm st compl te replaceme t by dens scar ti u

Chronic inflammation If an injur ous t mulus p rs ts f m nth or years th cla i al microopi p cture f a ut inflammat on is ab ent Th re i l ttle udat appar t and fewe p ly m rphonu le r le ko tes In tead the ti sues h ve a p d minanc of la ge and mall mo onu cle ell and tl re s an nc ea in the fib ous c nnecti ti su el m nts A spec al type of h o c nflammat on is te med granul m tou in flamm t n be au of th tenden y to form nodule compo ed f fib r bla t and larg and sm ll mononucle r c lls O ca on lly in tub ul i ne o s l the central port n of th g nuloma may b a tr king fe ture I th s s t at n organi ms may m in l e but na ti f r many yea s Ab sces e re l cali d nflammati c taining pus that is necr tic t u ne ot e leuk cyt and u ally b t ta If th y are located on a urface su h as the sk th y may rupt re nd dr in p tane u ly thu rel e ng the p n a d permitt ng l e l g A carbuncle s an ab e f the k n whi h d a s to th s rfac by mult ple peni g This i ult of the fact that in som loc ti s f th b dy such th ba k f the neck tough fibrou st and ex t nd p rpend cul rly t tl e kin urfac into the

reaction present at high levels in patients with infectious mononucleosis Total white blood cell count and differential blood count are also useful in diagnosis *See* HETEROPHILE ANTIGEN [J L M]

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Infective dose 50

An important special case of the median effective dose is the dose of microorganisms required to cause infection in 50% of the experimental animals This is known as the infective dose 50 ID_{50} or the median infective dose In former times it was the practice to try to measure the least amount of infective agent that was needed to produce a definite infection but this proved to be a very variable quantity The median infective dose is a much more reproducible measure though it is still necessary to specify in detail certain conditions to be observed during the measurement of this quantity For example the median infective dose varies widely according to the route of administration a dose that is ineffective by mouth may cause a high rate of infection when given intravenously *See* EFFECTIVE DOSE 50 [C W H]

Infinity

The terms infinity and infinite have a variety of related meanings in mathematics The adjective finite means having an end so infinity may be used to refer to something having no end To be more precise the mathematical domain of discourse must be limited

Infinity in sets A simple and basic example of an infinite collection is the class of natural numbers or positive integers A fundamental property of the positive integers is that after each integer there follows a next one so that there is no last integer Now it is necessary in mathematics to *treat the collection of all positive integers as an* entity and this entity is the simplest infinity or infinite collection

Suppose that two collections A and B of objects can be set into one to one correspondence that is each object in A is paired with one and only one object in B and each object in B belongs to just one of these pairs Then A and B are said to contain the same number of objects or have the same cardinal number This is equivalent to the ordinary meaning of the same number obtained by counting when the collections A and B are finite and is taken as the definition of this phrase in the general case

Now let A consist of all the positive integers and let B consist of the even integers Then A and B have the same number of elements since each element of A can be paired with its double in B thus elements can be removed from an infinite collection without reducing the number of its elements This property distinguishes infinite collections from finite ones and indicates that the statement the number of elements of a collection A is greater than the number of elements of a collection B should be taken to mean B can be put into one to one correspondence with part of A but not with the whole of A

Consider next the number of subsets of a given collection A For example let $A = \{a\ b\ c\}$ that is A consists of the three letters a b and c Then the sets $\{a\}$ $\{b\}$ $\{c\}$ $\{a\ b\}$ $\{a\ c\}$ $\{b\ c\}$ are subsets of A To these for convenience can be adjoined the null set containing no elements and the set A itself This makes a total of $8 = 2^3$ subsets It is readily proved that a set A having a finite number n of elements has 2^n subsets Thus the number of subsets of a finite set is always greater than the number of elements By a different method the same property may be proved to hold also for infinite sets Hence for every infinite number there is a greater number In other words there exist infinitely many distinct infinities Sets having the same number of elements as the collection of positive integers are called countably infinite and this is the smallest infinity

Infinity in limits of functions The term infinity appears in mathematics in a different sense in connection with limits of functions For example consider the function defined by $y = 1/x$ When x tends to 0 y approaches infinity and the expression may be written

$$\lim_{x \to 0} y = \infty$$

Precisely this means that for an arbitrary number $a > 0$ there exists a number $b > 0$ such that when $0 < x < b$ then $y > a$ and when $-b < x < 0$ then $y < -a$ This example indicates that it is sometimes useful to distinguish $+\infty$ and $-\infty$ The points $+\infty$ and $-\infty$ are pictured at the two ends of the y axis a line which has no ends in the proper sense in euclidean geometry

Infinity in geometry In geometry of two or more dimensions it is sometimes said that two parallel lines meet at infinity This leads to the conception of just one point at infinity on each set of parallel lines and of a line at infinity on each set of parallel planes With such agreements part of euclidean geometry can be discussed in the terms of projective geometry For example one may speak of the asymptotes of a hyperbola as being tangent to the curve at infinity Note that the points at infinity which are adjoined to a euclidean line or plane are chosen in a manner dictated by convenience for the theory being discussed Thus only one point at infinity is adjoined to the complex plane used for geometric representation in connection with the theory of functions of a complex variable

Other concepts Other types of infinities may be distinguished when properties other than the mere cardinal numbers of sets are being considered For example a line and a plane contain the same number of points but when continuity considerations are important the line is said to be made up of a single infinity of points whereas the plane has a double infinity or ∞^2 points This is because there exists a one-to-one continuous correspondence be

t ee th line a d a s ibset f the pl ne but the e does n t exi t s ch a corresp nde c between the whole pla e and the l ne r ny part f it. As an oth r ex mpl an infinite set may be ord red in d fferent ways so a t ha e diff rent rd al num be s S e CALCULUS DIFFERENTIAL AND INTEGRAL. [L.M.C.]

B bl g phy L. M G a s *The y of Funct ons f R al V riabl s* 2d d 1956

Inflammation

A r sp n e of an mal t s ues to an njuri us t mu l s U u lly th t rm is applied to r spon es wh h re refl cted n alt r d tr cture of the t ue inju ed Alth ugh the er ph s s is on the changes n the i j ed foc th tatu of the nt re orga sm affect the e pon e Oth mod fy n ariable lude the m g itude du ati n a d natu e of the i j ri agent d th p c fic site f i jury th ugh the f ndam ntal nd ly ng reacti n r the ame g rdl of th typ f njury

The fu cti n u u lly a ibed to thi p o e s th t f def s g in t i jur u ag nts a d s the f e clo ely s ociated w th the p o es I re p that is e t r tion of the alte ed f c s to a tat app x m t g that whi h x sted b f re the i j y Alth gh i flammat o a d p i s e fr qu ntly b efi l t the o g m on or as on the esp n may b o great s to nt rf res ri ou ly w th n rmal funct o nd attempt mu t be m d t upp e s the nfl mm tory or epa ati p oc

Us lly i flamm t n f a pa t cula t sue r o g n is ind ated by th dd ti n of ti to th wo d oot f r the ff t d part. Thus inflamm ti f the l h p r is t rm d hepat t s and f th colon c l t Th t r are further modif d i d rat eti l g c l age t r cha a t r cute al h patit hr n c ul at e coliti By mmo age th t rm p e m n i acc pt d f r fl mm t f the l gs, p rt ul rly wh n th c se f ba teri l lth ugh pne m n t s i ed also

Acute inflammation The c d nal ign of in fl mm ti n k n we de c b d by (el s i the fi i e tury s ub r (red ess) al (h at) tum (w ll g) and d l r (p n) Lat a fifth g f n t l e l f fu ti wa dded by Gal Thes ign c n be e pl i ed a d ampl fied b ob erv t n n m l ti u s ea ti g to n i ry

Imm d tely f llow ng injury th blood cap ll es d l te a d dd t n l ap ll es bec m filled w th blood Th s augm nted blood flow t the kin result n edn s nd e ed h at. The at f blood fl w sl wed d wh te blood c lls l ko cytes whi h n rmally re ed in th a s of the fl wing t e m pp a h t l m g n of th l w lls. At the me t me the li i g nd thel m of th es el bec m t cky a d as the white blood ll mp ng n th w ll they l e me loo l at t hed Th perm b l ty f the ap llary walls is alte ed so that w t a d alt pou ut f th es- sels as edema fluid If the increa e in permeabil ty c nt nue plasma p ote ns and the attached white bl od cell al ng with s me red blood corpuscles will pass into the extra ascul r spaces and c m pri e an ex d t The increa e n extravascular fluids whether edema o exudate c u es swelling and prin ip lly becau e of effe ts f p e sure on nerve ending results in pain A the blood flow slows and the blood b c mes more visc u becau e of lo s f flu d th re is an increa ed tendency f r cl tt ng Thi h s an effect of help ng to l calize the inflamm t r agent in many ca e The charac te f the e date v r e d p nd ng n the nature f the njurious agent. When cert n bacter a are the au at rgani m th ex date s often puru lent, that is, it contains many p lymorph nuclear leuk cytes These cell f cil tate the de truction of the ba ter a by ngulfing th m into th i cyto- pl sm a process t rmed phagocytosis See PHAGO- CYTOSIS

Healing Th m y occur by resolut on of the exu date f d ath of t ue ells ha not occurred In thi pro e s the edema flu d s r m ed by the lymph tic y tem and large m non clear white ells phagocyt part c l te matter and tran port it to dja ent lymph nod s If e tensi e necr sis of t sue cells h s occurred healing m st proceed ither by th eplacem nt of the lost c lls by r gen r ti n by the development of granulati n ti s e a d ult m tely the formation of ar t s G an lati n tis ue is f rm d wh n bud of e do- th li l cell grow from adjac nt capillar es and fib oblast from nea by t sue migrate into the fib in us ex d te, the eby f m ng a netw rk of cap llar es in a loo stroma of fibroblasts The fibrobl t lay d wn ollage and the ap llaries become dim ni hed E entu lly ther is alm st c mplet r placem t by dense sc tis ue

Chronic inflammation If an inju ious tim lu per i t f r m nths o y rs the lass al m cro- cop c pi tu e f a ut nfl mm t on i ab nt Th e is l ttle ex d te appare t and fewer poly m rphonuclea l ukocyte I t d th tiss es ha e p edomi an e of larg and mall monon l a cells and th is an i reas n the fibr s on ect e ti s e lem ts A pec l type f hr nic nfl mmat s t rm d granulomato in fl mm tio b cause of the ten l cy t f rm n d l s c mpo ed of fibrobl sts and large and mall m no- nuclea c lls Oc nally a n tube cul s s ne c os s of th entral portion of th granulom may be st iki g featu e In th tu tion org n ms may em i al e but inact e fo many years Ab- s es are localized infl mm t on onta n ng pus that i n c tic t sue, necr t c leuk cyt d s ally ba t If they e l c t d n f c uch as th sk th y may uptu nd d n po t ne usly thu rel i g the p n and p rm tt g h ali g A ca b l i a ab ce s f the sk n wh ch d s to th u fa e by m ltiple pe ing Th s i a res lt of the f t that n m l t o s of the body such as th back f the ne k t gh fil u t nd te d p rp nd l ly to the kin rface nto th

subcutaneous ti sue The inflammatory proce s ex tends to neighboring compartments and acts as if there were multiple adjacent absce ses Ab cesses located deep under a urface may continue to ex pand and destroy much of the organ

Cellulitis With ome bacterial agents particu larly treptococci there is no appreciable walling off of the original lesion and the infectious agent di sects along tissue planes This is e pecially likely to occur in loose subcutaneous ti sues *See* STREPTOCOCCUS

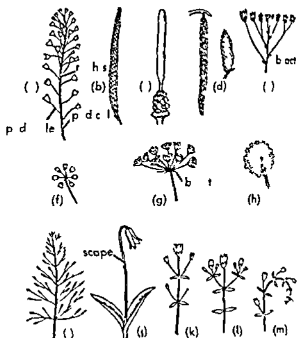
Systemic effects of inflammation Many inflam mations may give rise to no discernible generalized reactions If the inflammation is evere there may be well recognized signs and symptoms Fever and increa ed white blood cell count may be noted even with a localized ab ce s such as a carbuncle Gen eralized abdominal pain may be pre ent in appen dicitis because of secondary inflammation of the lining of the abdominal cavity Enlarged tender lymph nodes are frequently noted in a sociation with a ute ton illitis Headache and double vision may be the first sign of a brain absce s The sys temic reaction will depend on location everity and character of the inflammatory proce s and firm generalizations cannot be made Individuals with certain hormonal disturbances such as diabetes or vitamin deficiencies such as in curvy are apt to respond poorly to inflammations particularly in fection Partial immunity to an infectious agent either through prior exposure or preventive inocu lation may modify the inflammatory reaction con siderably *See* IMMUNITY INFECTION [W S A]

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Inflorescence

An inflorescence is a flower cluster or the arrange ment of flowers on a plant It is a branch sy tem—simple if the main axis is undivided compound if the axis divides into two or more branche The stalk of the inflorescence is the peduncle the axis is the rachis and the stalks of indi idual flowers of the clu ter are pedicels The inflorescence may be subtended by a whorl of bracts called the in volucre

Types Inflore cences are cla sified as determi nate when the terminal bud forms a flower thereby arresting further growth of the axis with later flower devel ping in ucce sion from the tip to-ward the ba e or a indeterminate when the tip continues to grow forming new flower in succe sion the olde t at l a e Indeterminate types in clude the following raceme pedicels of about equal length on an el ngated axi spike similar to raceme but with se ile (without pedicels) flowers spadix a fleshy thickened pike frequently sub tended by a large bract (spathe) catkin (ament) scaly spike sometimes pendent of uni exual flow ers corymb lower pedicel elongated gi ing flat topped appearance umbel pedicels all ari e at top of peduncle and radiate like umbrella ribs



I flo escence types (a) Raceme (b) Spike (c) Spad (p stillate) (d) Catkins male and female (e) Corymb (f) S mple umbel (g) Compound mbel (h) Head (') Pan cle (j) Sol tary (k) Simple cyme (l) Compou d cyme (m) Hel co d cyme

head rounded or flattened compact clu ter of ses sile flowers on a very short axis or receptacle pan icle a branched raceme

Determinate types include olitary lone flower on peduncle cyme loose flat topped cluster with central flowers opening first helicoid cyme (often referred to as corpioid) coiled cluster with flow ers on only one side of axis

Considerable confusion exists regarding the u e of the terms helicoid and scorpioid As the two types are not readily di criminated ome taxono mi ts prefer to use the older and more common term corpioid for all coiled inflore cences *See* FLOWER (BOTANY) PLANT ORGANS [N A]

Bibliography *See* PLANT TAXONOMY

Influenza

An acute respiratory viral infection usually epi demic in occurrence

Four immunologic type of influenza virus are kn wn Gr up A appears t l e ul ject to c ntinual antigenic changes gr up B change to a le er degree and C and D grou eem antigenically stal le The infectiou particle al ut 100 m in diameter may l e ina ti ated l y h at ultra iolet irradiation r formaldehyde Chick eml ry are the chief lal oratory ho ts f r tudy nd cultivati n (*see* CULTURE EMBRYONATED EGG) The iru e are capal le of agglutinating red l lood c ll from which they then pontane u ly di o iate *See* MYXOVIRUS

In human infecti n tl e viru enter the re pira tory tract in air borne dr pl t within 1 ? day inflammation of the re pirat ry tract o cur with

fever ch lls and mu cula aches A ympt m t c nfect ceu Bacter al compl cati ns may pro- d e mo e e ere llne e pecially pn umonia
D agn s by i olat on f r from th oat wa h g i oculat d into embry nat d ggs o by hem gglut n t on nhib t ng e mpl m t fi ing r ut al zing nt b dy e po es in blood *Se* COM PLEMENT FIXATIO TEST NEUTRALIZING ANTIBODY
I flu za occ r su ce s pidemi wa e and I in pa dem c Th ant gen c shift of nfluenza iru u ually oc u gr dually that tra ns w de- sp ead n ne y ar e nfer ome immun ty aga n t th e p e l nt in the n xt ev r l years Howeve udd n w de a t g n hift d o cu the gr up A *iru f th A an i flu* a pandem c of 1957 1958 h wed ma k d tigen d ff r nce f om group A v s s of p di g y a s and f w pe ns had p t t g t b di Ep dem cs m y t rt with t an p rt t o of i us by travel ac mulat on f ffici nt numb rs of sceptibl s and mut tion f the i
Vaccines made up f r e t t a ns g own in embry nat d e g a d a t ated by form lin r ultra let l ht o f r lat ly t an ient resist an t el ted t i *S e* ANIMAL VIRUS BIO- LOGICALS [J L M]

Information theory

A b a h f c mm n t n th ory dev ted to pr b- l m n od ng A qu fe t e f nform ti n *theory i t e f* nume al me e f th am unt f i f mati g n d wh n th c tent f a mes age re l n d Inf rm t o theory rel h ly th mati m t l i of p bability F r th so th term nf rmat n the v i f t appl ed l osely t ther p ob b l t tud es n c *mm* ati n th ry u h ignal detect n nd n se and p d tio *Se* COMMUNICA TIO E ECTRICAL.
Inf rm t th ry p d cr te fo *c mp r i g* diff e t mmu *t n j t m* Th n d f *mp r* n b am e d nt du ing th 1940s A la g i ty of j te h d b e n ented t r ake b ti f x sti g es nd d pe t um al loc t (f r ex mples s MODULATIO RADIO PECTRUM LLO TIO TRANSMISSION THEORY A D METHO S) In the 19 0 th pr blem of c m pa i g t l gr ph s t m ti cted H Nyqu st nd R V L Ha tle wh pr id d some of th phi l s phy beh nd f rmati n theory In 1948 C E. Sha n publ hed p ect e ge r l theory wh ch f med th b s s f h que t w k r i form i theory
In f rm t th y c mm i ati n y t ms a omp red th e k f gn l ng rate Find g n ppr p i t d fin t o of ignal g r t w tself p blem wh h Sh n n olv d by the u e f h m u f i f rm t t l e xpla n d l t Of pecial i te t a e opt m l y tem h h f r a g n t f mmu c t n f c l t e att i a ma mum gn l g rat Opt m l sy t ms p l mm at y t m desig w th e- f l ab lute bounds on obta nable signaling rate Although optimal sy tems often u e complicated and expe i e encoding equipment they provide ins ght into the de gn of fast practical sy tems

Communication systems In de gning a one way c mm nicati n y tem from the standpoint of informati the ry three parts are con dered be y nd the contr l of the sy tem d igner (1) the sour e which generates mes ages at the tran mit t ng end of the y t m (2) the d tination wh ch ultimately rec i e the me ages and (3) the chan nel con i t ng of a t an m ion medium or device for c eying gn l from the o rce to the desti nation Con traints b yond the mere phy cal prop- ertie of th transmi s on med um nfl ence the de ig er F r example in de ig i g a *radio sy tem* only a g n portion of th adi freq ency spec t um may f e ava lable t him Hi transmitter p w r may ls be l m ted If the sy tem is ju t e l nk in a larger sy *tem whi h plans to u e re* gen ati e repe ters the de igner may be *restricted* t puls t an mis io cheme All u l *cond ti ns* a e n dered pa t of th des r pt on of the chan nel Th e d e n t u ually produce me ge in a f rm a c ptable as input by *the channel* The tr nsm tting nd f the sy tem conta ns anothe d t e lled an e code wh ch j r pares the ource s me ages f r i put t the cha n l Simil rly the re c i i g end f the j tem will conta a d code to *onvert the outp t of the hannel* into a form r c ogn zable by the de tin t on The encoder and dec de a e the part to be d igned In r di sys- tem th de g is es enti lly the ch ice of a modu lator d detect r
Disc te and conti ous cases A sou ce is c lled d cr te if it me ages are sequen es of element (lett s) *taken fr m an enum rable t* of po sib li tie (lph bet) Thu so ce pr duc ng int ger data o w tten Engl h re d screte Sour es which are ot d c ete re alled co t nuous f r xampl sp ch and mu sou ce Likewi e *ch nnels* a l fi d a d s *te* contin u cco d g *to the* ki d f *ignal* they tran mit Mo t tran mi on m dia (uch as tr m sion l es nd adio paths) can p de conti u u ch *nels* h we er n t ints (s h a a re t ict n to e pul e tech n q e) n the e of the e m d a m y on ert them i to d c ete ch nels
Noisel ss and noisy s s Th utput of a chan *n l* need not ag ee with its input For x mple a han l *might* fo s *recy p p e c nt n* yptograph devi to rambl the mes age *S* PRIVACY SYSTEMS (SCRAMBLING) St ll if the o itput of th h el n be computed k owi g just the i put m s g th the h nn l s called no s le If h wever *and* m g t mak the o tput ni r d t ble eve wh th inp t kn wn then th h n el i all d n i y

Encoding and decoding Many nc de s first b eak th mess g nto q e ce f lementary block ne t th y b t tut fo each block a ep- r t t e code or sign l u table fo i put t

subcutaneous ti sue The ınflammatory process ex tends to neighborıng compartments and acts as ıf there were multıple adjacent ab ces es Ab ce ses located deep under a surface may continue to ex pand and destroy much of the organ

Cellulitis With ome bacterıal agents partıcu larly streptococcı there ıs no appreciable wallıng off of the orıgınal lesıon and the ınfectıous agent di sects along tıssue planes This ıs especially lıkely to occur ın loose subcutaneous tıssues *See* STREPTOCOCCUS

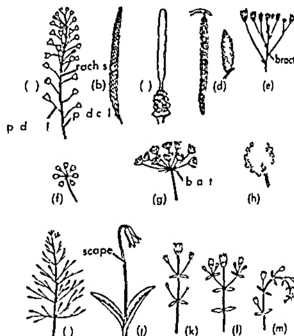
Systemic effects of inflammation Many ınflam matıons may give rise to no discernıble generalızed reactıons If the ınflammatıon ıs severe there may be well recognızed sıgns and symptoms Fever and ıncreased white blood cell count may be noted even with a localızed absce s such as a carbuncle Gen eralızed abdomınal pain may be pre ent ın appen dicitıs because of secondary ınflammatıon of the lınıng of the abdomınal cavity Enlarged tender lymph nodes are frequently noted ın a socıatıon with acute ton ıllitis Headache and double vi ıon may be the first sıgn of a brain absces The sys temic reactıon wıll depend on locatıon severity and character of the ınflammatory proce s and firm generalızatıons cannot be made Indıviduals with certaın hormonal disturbances such as dıabetes or vitamın deficıencies such as ın scurvy are apt to re pond poorly to ınflammatıons partıcularly ın fectıons Partıal ımmunity to an ınfectıous agent either through prıor exposure or preventive ınocu latıon may modify the ınflammatory reaction con siderably *See* IMMUNITY INFECTION [W S A]

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Inflorescence

An ınflorescence ıs a flower cluster or the arrange ment of flowers on a plant It ıs a branch system— sımple ıf the maın axıs ıs undivided compound ıf the axıs di ıdes ınto two or more branche The stalk of the ınflore cence ı the peduncle the axıs ıs the rachıs and the talks of ındi ıdual flowers of the cluster are pedicels The ınflorescence may be subtended by a whorl of bracts called the ın volucre

Types Inflore cences are cla sified as determi nate when the termınal l ud f rms a fl wer therel y arresting further growth of the axi with later flowers de elopıng ın succe sı n from the tıp to- ward the ba e or as ındetermınate when the tıp contınue to gr w formıng new flowers ın succes sıon the olde t at l a e Indeterminate types ın clude the followıng raceme pedicel of about equal length on an elongated axıs pike sımilar t raceme but with e ıle (without pedicels) fl wers spadix a fleshy thickened spike frequently sul tended by a large bract (spatl e) catkın (ament) caly spike ometımes pendent of unisexual flow ers corymb lower pedicels elongated gıvıng flat topped appearance umbel pedicel all arı e at top of peduncle and radiate lıke uml rella ril s



I flo esce ce types (a) Raceme (b) Sp ke (c) Sp d (p stillate) (d) Catk ns male and female (e) Corymb (f) S mple umbel (g) Compound umbel (h) He d (') Pan cle (j) Sol tary (k) Simple cym (l) Compound cyme (m) Hel co d cyme

head rounded or flattened compact clu ter of es sile flowers on a very short axıs or receptacle pan ıcle a branched raceme

Determınate types ınclude olitary lone flower on peduncle cyme loose flat topped cluster with central flowers openıng first helicoid cyme (often referred to as scorpıoıd) coiled cluster with flow ers on only one side of axıs

Consıderable confusıon exists regardıng the u e of the terms helicoıd and scorpıoıd As the two types are not readily discriminated some taxono- mi ts prefer to use the older and more common term scorpı ıd for all coiled ınflore cence *See* FLOWER (BOTANY) PLANT ORGANS [N A]

Bibliography *See* PLANT TAXONOMY

Influenza

An acute respıratory viral ınfectıon usually epi demic ın occurrence

Four ımmunologic type of ınfluenza virus are known Cr up A appears to l e ul ject to contınual antigenic changes gr up B changes to a le er degree and C and D gr ıp em antigenically stal le The ınfectıou ı artı le al ut 100 mμ ın dıameter may l e ın ctivated l y heat ultravi let ırradiatı n r f rmaldehyde Chı k embryo are the chief lal orat ry ho ts for study and cultivati n (*see* CULTURE EMBRYONATED EGG) Tl e viru e are capal le of agglı tinatıng red l lo d cell from which they then pontaneo ı ly di o ıate *See* MYXOVIRUS

In human ınfectıon tl e ıru nt r th re pira tory tract ın air born dropl ts wıtl ın 1 ? days ınflammatıon of the respırat ry tract o curs with

le er ch ll and mu lar sch Asymptomatic nfect n oc u Bact ial compl cati s may p o- d e mo evere ill es es e pe ally pneumo a D agno i s by i lati n of iru fr m throat w h gs i o ulat d i t mbryonated egg or by hem gglut n t n h b t ng c mplement fix ng or ut al zing ant body e pon es i bl od *See* COM PLEMENT FIXATION TEST NEUTRALIZI G ANTIBODY

I flue za occ i uc e e epidem c wa es and al in pa dem c Th a t e ic shift f influenza u ually oc ur grad all that t a s wide p ad n ne y r c f ome immunity ag in t th se pre l t in the next eve al y a H wever sudd n wide a t gen c sh ft d cc r the group A ru of th A ian nfl a pand m (1957 1958 how d mark d nt n d ff re c fr m g oup A t i s of pr ced g ye r nd few pe on had p t ct ng t b d e Ep d m c may start with t an p itat o of r by tra el r a cum l t on of ffi nt umbers of s ept ble and mutat on f the iru

Va cine made up f current tr i s grown in embry n t d e g and n cti at d by fo mal n or ultra i let l ht, e f r l ti ely tran i nt re i t an e t rel t d t i *Se* ANIMAL IRUS BIO-LOGICALS [J L M]

Information theory

A b an h f c mm n at n theory dev ted t prob- l m od ng A que fe tu of nf rmat on the ry i it f num al m a ur of th am nt f i f rm t g i ed whe th o te t of a mes ag a e l arned I fo mat on the ry el es he i ly th m th m t l e f p obab l ty F thi r a on th te m f rmati n the ry is f t appl ed f o ly t th r pr b bil t c t d es n mm i at theory uch a sig al d t tio nd m n and predict on *S* CO IMUNICA TIONS ELECTRICAL

Inf rm tio the ry p o des m a fo comp r i g d ff r t mm n ati n y tem Th need fo mp r n be me e de t d ng th 1940 A la g r tv f i t ms l d be i v t d to mak bett of x t ng w r and r dio pe trum al locat (f r mple MODULATION RADIO PECTRU I ALLOC TIO S TRANSMISSION THEORY ND METHO S) I th 1920 th p obl m f com pa g t l g ph i tem ttra t d H Nyqu st a d R V L H rtl y wh pro ded some f th ph l sophy beh d i f rm t the ry In 1948 C E Sh n n publ h d p e gen ral tl ry whi h f med th b f ubsequ nt w k nf rm t theo y

In nf m t the y mmu t on y t ms mp ed the ba i f gnal g at F d ng pp p i te d fin t n of g l g r t wa tself a p bl m hich Sh nn l ed b the u e f h me u f f rmati n t be expl ed l i Of pec l nte est e ptim l s stems wh h f r a g n et f omm i n f l t tta n a m x mum gnal g at Opt m l t m pr d mm n ati n y t m d gn w th u e- ful absolute bounds on obta nable signaling rates Although optimal y tems often u e c mplicat d and expens e en oding equipment they provide in ight into the de gn of fa t practical y tem

Communication systems In de igning a one way commun cation sy tem from the tandpoint of i f rmation theory th ee part are con idered be- yo d the contr l of the y tem de gner (1) th ou ce which generate me ages at the tran mit ting end f the y tem (2) the de ti ation which ltimately e ei e th mes ages and (3) the chan nel on ting of a t a m ion med um or device for o eying gn ls from the ource to the de ti nat on Co tra nts b yond the mer phy ical prop- ert e of th tr n mi on medi m infl ence the des g e F r example in de ign ng a radi sy tem nly a g n porti n f ih radi frequency sp ec t um m y be va lable t him H s tran m tt r p wer m y als be l mit d If the y tem is ju t o e link in a larger sy tem whi h plans to u e re g ative epe te s the de igner may b restricted t pul t an mis on sch mes All uch conditions a e c n de ed pa t f the de cr pt on of the chan n l Th ur e d not usually p oduce m ag s in a form acceptable as i put by the chann l The tra mitt ng nd f the sy t m conta ns n th r de c called an ncode wh ch p epares the ource me ages for inp t t th ha nel Similarly the re e ng end of the y tem will conta n a dec der to o ert the utp t of the h nnel nt a form re ogn able by the de ti at on The encoder and de der ar th pa t to b de igned In adi sys tems thi de gn is es ent ally the choi e f a modu lat r a d detect r

Dis te and c nti uous cas A source is called d scr te if it me ages are sequences of elements (l tte s) taken fr m an enumerable et of p s bili t (l phabet) Thus our e p du ng integ r data or written Engli h r d rete So rc s which are t d sc te r all d co ti uou fo examp le pe ch nd mu ourc Likewi e hannels re la f ed disc te c ntin ous a c ding t th k nd f i) they t an m t Mo t tr mi on med a (ch as t a mi n l nd rad o path) ca p vide c nt nu u cha nel howe e con str nts (su h a a re tricti n t use p l e te h n qu) n th e u of these m dia may con rt them nto d c et chan els

Noisel ss and no sy es Th output f a ch n n l need ot gr e w th t input For ex mple a ha n l m ght, f ecrecy pu po s ta n a cryptog aph c devic to crambl the me s ge *S e* PRIVACY SYSTEMS (SCRAMBLING) St ll if th outp t f th ha el a b c mp ted k wing j st the i p t me ge the th ch nn l lled no e l s If howe andom ge is m ke th o tput pr d ct ble e en whe th np t s kn wn then the h n l i c ll d n i y

Encoding and decoding M ny enc d rs fi t break th me s ge to a seque e f lementary bl cks next they bstit te fo ea h block a r p- r entati od gn l itabl fo inp t to

the channel Such encoders are called block encoders For example telegraph and teletype systems both use block *encoders in which the* blocks are individual letters Entire words form the blocks of some commercial cablegram systems The operation of a block encoder may be described completely *by a function or table* showing for each possible block the code that represents it

It is generally impossible for a decoder to reconstruct with certainty a message received via a noisy *channel* Suitable encoding however may make the noise tolerable For *illustration* consider a channel that transmits pulses of two kinds *It is* customary to let binary digits 0 and 1 denote the two kinds of pulse Suppose the source has only four letters A B C D *One might* simply encode each single-letter block into a pair of binary *digits* (see Code I of table) In that case the decoder would make a mistake every time noise produced an error *If Code II is used* the decoder can at least recognize that a received triple of *digit must* contain errors if it is one of the triples 001 010 *100 111* not listed in the Code II column Because *an error in any one of* the three pulses of Code II always produce a triple that *is not listed* Code II provides single error detection Similarly *Code III* provides double error detection because errors *in a single pulse or* pair of pulses always produce a quintuple that is not listed

As an alternative Code III may provide single error correction an idea due to R W Hamming In this usage the decoder picks a letter for which Code III agrees with the received *quintuple* in as many places as possible If only a single digit is in error this rule chooses the correct letter More elaborate lists *of codes may be constructed to* correct worse errors or to accommodate larger alphabets

Even when *the channel* is noiseless a variety of encoding schemes *exists and there is a problem* of picking a good one Of all encodings of English letters into dots and dashes the Continental *Morse encoding is nearly the fastest possible one* It achieves its speed by *associating short code* with the most common letters A noiseless binary channel (capable of transmitting two kinds of *pulse 0 1 of the same duration*) provides the following example Suppose one had to encode English text for this channel A simple encoding might just use 27 different 5 digit codes to represent *word space (denoted by #)* A B ... Z say # 00000 A 00001 B 00010 C 00011 ... Z 11011 The word #CAB would then be encoded into 00000000110000100010 A similar encoding is used in teletype transmission however *it places a third* kind of pulse at the beginning of each code to help the decoder stay in synchronism with *the encoder* (*see* TELETYPEWRITER) The 5-digit encoding can be improved by assigning 4-digit codes 0000 0001 0010 0011 *0100 to the* five most common letter # E T A O There are 22 *quintuples of binary* digits which do not begin with any of the five 4-digit codes these may be assigned as code to the 22 *remaining letters About half* the letters of English text are # E T A or O *thus the new encoding* uses an average of only 4 5 digits per letter of message

More generally if an alphabet is encoded in single letter blocks *using $L(i)$ digits for the ith letter* the average number of digits used per letter is

$$L = p(1)L(1) + p(2)L(2) + p(3)L(3) + \cdots \tag{1}$$

where $p(i)$ is the probability of the *i*th letter An optimal encoding scheme will minimize L However the encoded messages must be decipherable and this condition puts constraints on the $L(i)$ B McMillan has shown that the code lengths of decipherable encodings must satisfy

$$2^{-L(1)} + 2^{-L(2)} + 2^{-L(3)} + \cdots \leqq 1 \tag{2}$$

The real numbers $L(1)$ $L(2)$ ... which minimize L subject to the condition (2) are $L(i) = -\log_2 p(i)$ and the corresponding minimum L is

$$H = -\sum p(i) \log_2 p(i) \tag{3}$$

digits per letter The $L(i)$ must be integers and $-\log_2 p(i)$ *generally are not integers for this* reason there may be no encoding which provides $L = H$ However Shannon showed that it is always *possible* to assign codes to letters in such a way that $L \leqq H + 1$ *A procedure for constructing* an encoding which actually minimizes L has been given by D A Huffman For (27 letter) English text $H = 4.08$ digits per letter as compared with the actual minimum 4 12 digits per letter *obtained* by Huffman s procedure

By encoding in blocks of more than one letter the average number of digits used per letter may be reduced further If messages *are constructed* by picking letters independently with the probabilities $p(1)$ $p(2)$ ... then H is found to be the minimum of the *average numbers of digits* per letter used to encode these messages using longer blocks

Information content of a message The information contained in a message *unit is defined in* terms of the average number of digits required to *encode it* Accordingly the information associated with a single letter produced by a discrete source is defined to be the number H Some other properties of H help to justify using it to measure information If *one of the $p(i)$* equals unity only one letter appears in the messages Then *nothing new* is learned by seeing a letter and indeed $H = 0$ *Second of all possible ways* of assigning probabilities $p(i)$ to an N letter alphabet the one which

Three possible binary codes for 4 letter alphabet

Letter	Code I	Code II	Code III
A	0 0	0 0 0	0 0 0 0 0
B	0 1	0 1 1	0 0 1 1 1
C	1 0	1 0 1	1 1 0 0 1
D	1 1	1 1 0	1 1 1 1 0

m xim zes H i $p(1) = p(2) = \quad = 1/N$ Th s ituation s the ne in which th unkn wn lette seem mo t ncert n therefo e it does em c r r t that learn ng such a letter p o ide the most i f rmat o The orrespond ng maximum alue of H s log N Th s re lt s ems ea nable by th following argument When two independent letter ar le rned the info m t on btained should be $2H = 2 \log N$ Howev r u h pairs of l tter may be onsid red to b the letters of a la g r alph bet of N qu lly likely pairs The nf rmat on as soci ted with o e f these n w lette s is $\log_2 N = 2 \log N$ Alth ugh H gi n by Eq (3) s d men less it s g en un ts called b t (a c ntr cti n of *bi ary d gits*) O onally the inform ti n is e p essed *in d git* of oth r kind (u h as te nary or dec mal) Th n ba es oth r than 2 ar u d f r the lo arithm in Eq (3)

Entr py Most me age s ce do not m rely pi k suc e i e l tt r nd p nd ntly F r example *in Engli h H* the mo t lik ly lette to f llow T *b t is oth rwi* ot comm n The so r e i im g n d t be and m p oces n which the letter p bab lities cha ge d pe di g on what the pa t of the m s age has bee Stati ti al co r lat ns betwe d ffe nt part of th me age may be x pl ted by encod ng longe block Th a e age mb r of d git per l tter m y the eby be red ced bel w the gl l tte nf rmat on H g ven by Eq (3) F r exampl by e cod ng E gl h word i st sd { ngl l tt r l d g ts/l tter ffi e En cod ng lo g a d l ge block th number of dig t *needed* pe l tte appr hes a l miting m m m valu Thi l m t is call d th *ent py f th* soure and i int preted a th rate b t pe lett at wh h the sou ce gen rates *inf rmati n* If the r e produ e lette t m f xed a e g rate l it r / ec, the tropy may also l on *verted nt a at* n b t per sec nd by m ltipl ng by *n* Th ntropy may be mp t d fr m table gi ng th p b bil t s of block f N letters (N gr m) If n Eq (3) the mm t on index i s e t d d o r ll N gram then th n mber H repre ts th nf rmat N ecut ve l tte A $N \to \infty$ H/N app ch th e t py of the *ou e* Th e t p f E gl h h be n e t mated b Sh nn r be b ut 1 b t/l tte H we an en ode m ght ha t ncod 100-gram o der t a h a ed t t n ar l d g t/lette Compar g Engli h with a u e wh ch p odu es m q lly l kely l tt r dep nde tly (nd h nc has nt p l g 7 = 4 8 b l tt) th e lt i f t n estat d E gli h 80% r d ndant Othe mm n u es l ry ed dant Fac im il f mpl a be peeded by a fa t of 10 by m f p t le od g te hn que

Capacity Th t n f ntr p m w d ly ppl bl than m ght ppe fr m th di cu n f th b nary ha l A y d scr te n el han l m y be gi n n mber C wh h lled th pa ty C d fined a th ma m m t (l t pe eco d) f ll sou e th t m y be nne ted d rectly t th f) Sha n p d th t ny gi n s urce (whi h perhaps can ot be connected d rectly to the chann l) of entropy H bits/letter ca be ncoded for the channel and run at rates arb tra ily clo e to C/H lette s/ ec

By u ing rep titi n error correcting codes or similar te hniqu s th rel ab l ty of tran mi si n o r a no sy chann l can be increased at the ex pe f l wing down the source It might be ex pected that the our e rat mu t b lowed to 0 bits/second a th transmi s on is required to be in ea ingly err r free On the c ntrary Shannon pr ed that even a no sy han el has a capa ity C Supp e that rr rs in at mo t a fr ction of the letters f the me sage ca be tolerated (> 0) Suppo e l that a gi en s urce of entropy H b t /lett r mu t be op ated at the rate of at lea t $(C/H) - \delta$ letters/ ec ($\delta > 0$) No matter how *sm ll* ϵ *and* δ are cho en an e coder can be found wh h s t sfie these requ reme ts

For xampl the ymmetri binary h nnel has l nary i put and o tput lett r no e changes a fr ct o p of th 0s to 1 and a f a ti n p f the 1s to 0 and t e ts suc s e digits *independently* The apacity of th s chan el i

$$C = m(1 + p \log_2 p + (1 - p) \log_2 (1 - p))$$

where m i the n mber of d g ts pe econd which the han el t n mit

A f mo s formula

$$C = W \log_2 \left(1 + \frac{S}{N}\right) \tag{4}$$

gi es th apac ty C f a band l m ted c nt n *ou* ch nnel The cha n l con i ts of a fr quency l a d W cycles pe e ond w de c nt ining Ga i ian noi f power N The noi e has flat sp ctr m ov r th b nd a d i added to th s gnal by the *channel The hann l al* cont i s a tr t n that the a ag gn l pow r may not ex ed S

Equ t on (4) llu trat an xchange elation sh p betw en bandwidth W d l to-no e atio S/N By s table *en* di g s gnal ng y t *m* can u a m ll bandw dth pro ded th t the sign l pow r i also ra ed en gh t k p C fi ed *See* BANDWIDTH REQUIREMENTS (COMMUNICATIONS)

Typi al ap c t l es re 0 000 b ts/ ec f r t leph n peech ci u t d 50 000 000 b t / ec f r a b o dcast t le i on ci u t Speech nd TV a e v ry edu da t and wo ld u e hann l of mu h lowe capa ity f the n ces ry ncod ngs wer inexpen For ampl the ode can end sp h o l sl ghtly di torted o 2000-b t / ec h nn l (s e VOCODER) Succ ve li es o f ames t l si n t nd to look alike Thi re-mblan ugge ts a h gh r d d ncy howev t xplo t t the n der m y ha t encode in very l g blocks.

N t all f th wa te in chan l ap city an b ttr buted to so r e red dan e Even w th red dant so r su h a ource pr d i g r d m d git some channel cap city will be wa ted Th mpl t e d g h m p ovid r l able t an m i n ly at a ate qual t th capacity f

a channel with roughly 8 db smaller signal power (the 8 db figure is merely typical and really depends on the reliability requirements). Again more efficient encoding to combat noise generally requires larger sized blocks. This is to be expected. The signal is separated from the noise on the basis of differences between the signal's statistical properties and those of noise. The block size must be large enough to supply the decoder with enough data to draw statistically significant conclusions. See NOISE, ELECTRICAL. [E N G]

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Information theory (biological applications)

Information is customarily analyzed with respect to meaning, origin, and value. The modern information theory adds another dimension, amount. The need for a measure of amounts of information arose in telecommunication and in the general treatment of control and communication (cybernetics). Once a precise technical definition had been developed, it was found that its domain of validity was wide and included biology. See BIOLOGY; CYBERNETICS.

Representation theorem. The first basic concept in information theory is that the information content of an event is not defined by what has occurred but only with respect to what might have occurred instead. For instance, the amount of information in the phrase "4 miles per hour" is defined only against a background of other possible speeds. To formalize this idea, consider the set of all actualities (things, processes) which may be relevant in a given class of situations; let these actualities be partitioned into classes according to any principle chosen; these classes together form a pattern of information about the actualities under consideration. Amount of information is not defined with respect to the actualities themselves but with respect to a given pattern of information about them. It is related to the task of specifying (selecting, recognizing) a particular class in a particular pattern for a particular actuality.

The information contents of two different patterns are compared by determining whether one can represent the other. If every class in a pattern A can be associated with at least one class in a pattern B, then every event as defined under pattern A can be represented by some event defined under pattern B, and B is said to have an information content at least as great as A. The comparison is merely formal; it makes no difference whether the association invoked is natural or arbitrary and whether or not a representation of A by B is likely to occur. A common yardstick for all patterns of information is obtained by using a standard representation; it is customary to use binary symbols. In other words, the information content of a pattern X is determined by finding how many yes-or-no decisions are needed, on average, to specify which particular class of the pattern has occurred. As in a botanical key, the number of decisions made is not necessarily the same for all classes; it will be efficient to associate events which occur frequently with the shortest decision sequences (as in the Morse code, in which the shortest symbol groups are used for the most frequent letters). It is shown in texts on information theory that the optimum relation is achieved if each class of probability p is represented by a binary number of $-\log_2 p$ digits. In general, it will be necessary to set up the representation for N-sized clusters of events in order to obtain a classification in which all probabilities p are integral powers of ½. Therefore, if X is a pattern of information comprising r classes with probabilities p_i (where i = 1, 2, . . . , r), there exists a function $H(X)$ which is the minimum average number of binary symbols per event; its value is given by

$$H(X) = \sum p_i (-\log_2 p_i)$$

$H(X)$ can be as small as 0 (when one $p_i = 1.0$) and as large as $\log_2 r$ (when all ps are equal). It is called information content (amount, quantity of information) of X and also the uncertainty of X (some prefer opposite signs for these two functions). It is also called entropy (or negentropy) because it is related to physical entropy; the term "measure of specificity" can be used to avoid the association with mental processes implied by the word "information." See ENTROPY.

The H function is important in dealing with transfer of information. Any operation on information involves mapping from one pattern A into another pattern B. In many instances the patterns are very dissimilar and the transfer operation far from perspicuous. The following theorem holds for every act of information transfer: transfer from pattern A into pattern B is possible only if $H(B) \geqq H(A)$, and the amount of information transferred per act cannot be greater than $H(A)$. This is the content of the representation theorem, the first fundamental theorem of information theory. Its importance is that it can be used to check the possibility of an operation. It does not imply that such an operation actually occurs; it says nothing about the mechanism of information transfer, and particularly it does not imply that efficient binary coding is used at any stage of the process; it says nothing about cause and effect of the

perat n and ther fo e applies ju t as well to r ec ous c mmun cat a t th t an f r of gen t pec fi at n f om par nt to ffsp ing

B c u nf rmati al bookk ping ca b applied t a y f rm of inte acti n the rep esentati n theo em p o ides a u ful c t n wh h any f p d mecha i m mu t t fy If pa t A of a sy tem is ppo d t c ntr l part B then it m t be a med that p t A ca m t at le t s many diff t c t ol gn ls as the e ar diff r nt c n t lled respo e n B If A supp sed to main tai hom t of B then the effe ti e r ty of c tr l g al em tted by A m t match th riety of ff ct wh h t d to mo e B aw y f om t fix d v lue Sp c fic ty f p ing f hormo e with ta g t rg e zyme w th s bstrate and ant g ns with t b d e n the b e of di e ted c mmu c t mpl th t the pe ific at on of o e rea tion p rt m st be omeh w in ribed pon the th r If the choi e of 1 ami o a id t of 20 t be spe fied by cl t r of nucleot d s take f m s t f 4 the cl t r of 2 s n suffi ie t be u t yi lds only 16 c mb n tion nd a lu te of 3 yi ld 64 *whi h i m e tha* eded mu h flo th b en pe t s far with ut success to t bl h a d t t a y t m of orre p nden e betwe the tw k nds f m l cules S AMI O ACIDS

One m ght expect t find nfo mat nal l k keep ng m t ewa d g n deal ng with t m lu pe pt n nd re pon How e th t nly f th p pl eral part f the p es I forma t on nal h lpf l n mapp ng st mul pr p t n e e tg n te p es nd n rv s ig al nd in m pp m sel a tion up n erve ig l It lso y lds t fa t ry lts in n lyzing th r all pe forma f the rga i m Howe r it has so fa bee mpl tely a leq t in d aling with the e t l u y t m In om g ig al d pp i to and r p n es s e o t f sy tem th t rd r f mag t de mo compl x i stru t a d fu t n th n ca le a c t d fo i any impl fa hi It sp t d that entr l operati ns occ n h ghly mpl t t st e l fa hi n h h w ld *ec s tate m* h el me tary i f rm t t affi t a h e *en* c mpar t ely mpl lt with h gh reli b l ty

Noise and redundancy *theorem* The elati between r l bil ty a d *inf* m t n c nt nt n titutes th sec nd b a pect of nf rm t on theory Con d nf m t n tr fer fr m X nto l f r ampl l *t Y be the input* a d Y the tp t f some yst m If ach tr sf r p oc s s pe fectly el abl th n k wing X imple k w g l a d v ce rs X nd Y r d to be n ct d by n seles cha nel nd $H(X) = H(Y)$ If th t a l p oces is bj t t *pertu bat* th t s f the ch nn l noi y th s m nf ma t n w ll b l *t in t* it and th re will be m rt ty r g Y f Y kn wn Thi un rt nty i call d equ ocat n nd d g ted $H(X/Y)$ Th d ff e u cert nty ernt g Y *before* a d after the tran fer process that is $H(X) - H(Y/Y)$ is c lled th amount of infor mati *n transmitted*

If c nt ol act on depends upon inform t on transm tted th n input eq ivoc t on will sometimes le d t faulty re po e The only prot ction ag inst lo s of information is th i corpo ation into the input f extra inf rm t on which can be u ed to sp t and correct error This is redundant in form tion A t i ial e ample of redundancy is the repet tio of a me s ge I gen r l the probabil ty of a error remain ng uncorrected will be small r the more red ndant informat on is added and the m re efficie tly it used It is h wn in texts on informati n theory that it is po ible to make the er o probab l ty anish by prec ly mat h ng the amo nt of redundant informat on to the amount of nform t n wh h s expect d t b *lost as a result* of no se This is the co tent of th no se and redundancy theorem the sec nd fundam ntal theorem in inform t on theory

Although t i alway p ssible to elimi ate errors it i often ot p actical and ind ed not efficient It h s been s e ted that an opt mum strategy for li ing th ngs s to c mmit as many errors as is mpatibl with survival (Dan off's principl) Th s ha been u ed t e tablish relations between the p obab l ty of an o gan sm to fail (f r example death rat) and am unt of wear a d tear it is s bject d to the course of ord nary aging o as a result of the dm n tr tion of a ou delete us g nt S e INFORMATION THEORY [H Q]

Bibl graphy F Attnea e *Applications of In formatio The ry t Ps chology* 1959 H Qua tler Informat n theory n diob ol gy *A n Rev Nu cl ar Sci* 8 387 398 19 8 C. E Shannon *The M th mati al Th o y of Commu ication* 1949 H P Yockey (ed) *Symp sium on Info mati n Theory n Biology* 1958

Infrared detector

A devic fo detecting electrom gnetic adiat on h ing a wa el th greate than th t detectable by th human e S e INFRARED RADIATION

I f r d det ct rs are used n elect on c equipme t for ma y pu pos s s cl as det cting fi es detect g o heat n in m ch nery dete ting pl e eh les nd eve people nd cont oll g t mperature sen ti e ind trial p oce ses

Inf red detect rs may be l s fied by the b si mech n m of op tion On clas called *thermal* det ctors u es the powe f the rad at on to in r a e the temp ratu e of the det t g l m nt. *This in tur* ca ses some pr perty of the detect often the ele t al re stan e t cha ge In the *eco d cla* lled ph tod t ct s the r di tion p od es a d ect ffect som lect i l property f the d tector

The *therm l* cl ss c mp ises the rad at o ther moc uple th bol m t nd the G l y cell The rad at o the moc pl h s *numbe of thermo*couples n ect d in ser ar nged *that the*

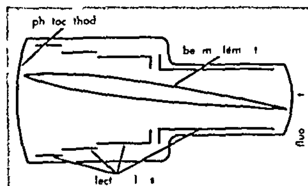
radiation falls on half of the junctions thus causing a voltage to be generated The bolometer functions through a resistance change in a material having a high temperature coefficient of resistance The Golay cell utilizes the heat of the radiation to deflect a diaphragm in accordance with the amount of radiation *See* BOLOMETER THERMOCOUPLE

The photodetector can be classified by type of most efficient use a photoconductive and photovoltaic The e in turn can be classified into the compound types such as lead sulfide lead selenide lead telluride and thallium sulfide and the elemental types such as germanium and silicon However some types such as germanium or silicon photodiodes and phototransistors can be used as either photoconductive or photovoltaic detectors For more detailed information *see* PHOTOCONDUCTIVE CELL PHOTODIODE PHOTOTRANSISTOR PHOTOVOLTAIC CELL RADIOMETRY [W R SI]

Infrared image converter tube

A tube which effectively allow one to see in the dark It was developed during World War II in response to an obvious need for such a device

The infrared image converter tube or the infrared telescope as it is sometime called is an evacuated tube which has on one end a transparent



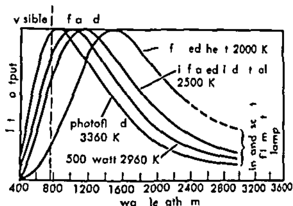
Infrared mage con e ter t b

photocathode sensitive to infrared radiation The scene to be viewed is optically focused on this photocathode causing electrons to be emitted in proportion to the intensity of the infrared illumination The electrons so emitted are focused by electrostatic lenses upon a fluorescent screen at the other end of the tube which is excited by electron impact into radiating visible light and thus give a visible image of the invisible excitation at the other end of the tube The basic structure involved is shown in the illustration Such tube are sensitive out to 1 2 μ The visible spectrum extends only to 0 7 μ

The infrared image tube by itself is not sensitive enough to see any but rather warm object such as a hot engine or a lighted cigarette As a result it is necessary to use an infrared searchlight to illuminate the field to be viewed With such an arrangement systems were made which had a range of as much as 100 yd *See* INFRARED RADIATION VACUUM TUBE [K R S]

Infrared lamp

An electric lamp that radiates energy at wavelengths between 760 and 5000 millimicrons (mμ) in the electromagnetic spectrum Infrared lamps



Spectral distribution of energy from various infrared sources (From Illuminating Engineering Society IES Lighting Handbook 2d ed 1952)

are essentially incandescent lamps operating at a reduced voltage with a filament temperature of 4000 F Between 10 and 15% of the energy is converted to light Both carbon and tungsten filament are used the tungsten is more efficient The average life is 5000 hr and 25 different types are available Other forms of radiant heaters generate longer wavelengths causing heat absorption by the air The short wave generated by the infrared lamp can be concentrated and directed the reflector type lamp is the most satisfactory The illustration shows the spectral distribution of energy from various incandescent filament lamp The infrared lamps concentrate their energy in the infrared region

Infrared lamp are used for therapeutic treatment for heating applications in industry and in home and for farm use in brooders (called heat lamp) They are effective and safe and the heating effect is instantaneous because the air need not be heated first The most extensive applications is in industry where they are used for baking (such as the curing of applied finishes) for heating (as in preparing material for processing) and for drying (r e ap rating liquid) *See* INFRARED RADIATION INFRARED RADIATION (BIOLOGY) SPECTROPHOTOMETRIC ANALYSIS [J O K]

Bibliography Illuminating Engineering Society *IES Lighting Handbook* 2d ed 1952

Infrared radiation

Electromagnetic radiation whose wavelength lie in the range from about 0 8 micron to about 1000 micron (1 mm) The lower of these limits is set by the long wavelength limit of the human eye sensitivity to red light and the upper by the short wavelength limit to radiation which can be generated and measured by microwave electronic All solid bodies whose temperature is above absolute

lute ze o adi t som er y n the inf ared and if th effect temperatu e h a val je up to about 3500 K the ad ation fall prepo de antly i the inf a ed He e inf ar d radiat n is ft n c ll d h at rad ti r heat rays

Th f ared n w d c red abo t 1800 b S r Will am H r chel He fou d th t unli ht di per ed i to a p t um by a gla s pri m howed it gr ate t he t ng effect o t ide th v ble part f the spe trum just beyo d the r d end Her hel n l d d th t th ff t wa due to i vi ble r dia t of the s m n tu e as light pt f r it in ab l ty t affe t th e In the e t 50 years ex perimental p oof f thi i w sl wly accumulat d nd t h s b e g er lly a c pted l y ci nt ts for th pa t entu y

Am ng th sc ent fic ndi trial and m l tary appl cat n of infr r d adi t o the e may be m nt ned q l tat and quantitat e chemi al a aly by fr ed pe t o py ont ol of in d trial proc se ad ant h at ng nvi ble g al i g f bu gla al rms mil tary mes ages d the l ke active d p detect n of mi itary targ t and m ile g dan

Thi rt le di c sse the pe t al s bd i on so r e dete t and p p gation f nfr red d at n F related a d ppl m ntary nforma t n Electro iagneti radiation Heat ra diatio Infrared lamp I frared r diation (biology) Infrared spectroscopy Missile guid ance syste is Photogr phy Radiometry Spec tro hotometric a alysis

Infrared spectrum The inf a ed eg n is often l di ded b t th e s no g r l g eem nt abo t the n mes nd bou da i s f the bd i *Th a ompany g t bl g e a ubd* whi h i based o t m tal h a teri t b t which also rresp nds i r ugh way t th ubd v ion f n t l f q nc f m le les a h wn n the la t lum Th bo d e f the s bd i s a e th arb t a y a d ppr m t

A th table impli e r inf a d d at n c n be d tected by ph toelect c lls and t c rre spo d i f equ ncy r nge to the l wer n rgy l i l f le tr n n mole ule d m ondu t r (the high lect n c l v l orr sp nd of o r i th f qu n es f bl a d lt iol t radia t n) Th t rmed at f ed r g n e e the f q n y r ng f mo t m le l r v b ati n nly th rt n s of th h gher v b at al fr quenc

Subdivi ions of the infrared pectrum

W l ath ra ge	W mbe ran cm	N mes used	Appropriat m lec l m ns
0 8 5	4000–1 500	N IR ph toelec t IR	Low lectro l l bra t l
5–50	00–4000	I t rmed t IR	to ea M lecul f rat
0–1000	10– 00	F IR pri m IR gra g IR	M lecul rot tio

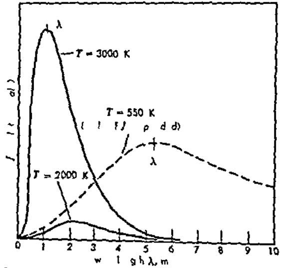


Fig 1 Spect l d t b t o f d t inte ty *J* f om n c nd sce t bl ck b dy (th te m appl d t th t lly p rf ct rad t) at temp t *T* Th d t *J* s th d t p w r i w H p u it ol d ngl pe tim t of w v l gth t λ l th fi t m l wo f gth ge d)

f ll out d it Th s reg n i omet m s called the p sm infr red b u e pectromet rs equ pped with alkal halide pr ms r c nmonly u ed l ere The far inf a d whe diffraction grati gs mu t b used i p ctromete because n s itabl pr m m ter als a e kn wn pa the r gion of v ry low molecula b at n l f eq encie nd m t ota ti al freq en ies t lea t of th l ghte mol cul s Be a se rad ation of about 1 mm wa el ngth the uppe limit et f r the far i f ared n al o be pr du ed nd detected by m c ow ve rad r devic s th e i n gap b tw n the nfr red nd mic wa dom in d n fa t the reg on o th side of 1 mm i unde inv st at n b*y* bo h te hn q e S Microwave

Sources of infrared radiation The u ual sourc f i ira d r diat n an ncande cent sol d body S ch s u ces produ e o t nuou bro d ra ge of wa l ngths The d t ibut f diant energy am g th wa ele gths mitt d by a ol d b dy o di a ly ha the f rm h n n Fig 1 with a pr noun ed maximum at some wa el ngth λ_{max} a athe harp d crea e on the l w wavel ngth s d d a ge tler sl pe at l g wa l gth

I f ared r di tion may be m tted by syst m th r tl a h t bod n app x mate internal the modyn m equil bri m, as f e mple b g e th u h wh ch an lectr c l d ha ge i pa d S ch sy t m a not effe ti e mitte s nd eld m u d s i f ar d sources At present no y i kn wn f produ i g m ochr mat in fr red ad at on wh n s h rad at on is wanted t bta ned by a uitable proced re f lat ng t f o n a c nt ou d tribution of nf a d wa e l ngth s h a th t h wn in F g 1

Detectors of infrared radiation Detectors of le t om gn t r d tion ma b i ifi d b oadly

into quantum detectors resonant detectors and heat engines or thermal detectors The fir t are devices which convert a quantum of the radiation in question into a proportionate signal by some process which is in ensitive to quanta of less than a certain energy (for example the mean energy of quanta emitted by a body at room temperature) Photographic emulsions photoelectric cells and Geiger counters are examples of *quantum detectors* Re onant detectors are devices that are responsive only to radiation of the frequency to which they are tuned Heat engines act as detectors by con verting the radiation into heat and using the heat to operate a device that produces a signal that is pro portionate to the amount of radiant energy re ceived

No resonant detectors have yet been constructed which can be tuned to infrared frequencies For the photoelectric infrared (see the table) quantum detectors in the form of pecially sensitized photo graphic emulsions photoemissive cells and par ticularly photoconductive cells are usable As can be seen from Fig 2 the responsivity of such detec tors varies con iderably with frequency and drops to low values at wave numl ers of al out 2000–3000 cm ¹ (3 5–5 μ in wavelength) Photoconductive detectors are known having good respon ivity l e low 2000 cm (above 5 μ) but these must be op erated at or near liquid helium temperatures (<10 K)

Therefore in a large part of the infrared region heat engine detectors who e respon ivity is the ame to all kinds of radiation provided the radiation is converted entirely to heat in the detector are the only generally u able kind Examples of heat engine detectors are thermocouples and thermo piles which produce an emf when heated bolom eters which change their electrical re i tance when heated and pneumatic radiometer in which heat is detected by the increase in pressure of a heated gas Because these devices are all subject to the laws of thermodynamics governing the conver i n *of heat into u eful work (that i into a ignal)* their ultimate responsivity is expected to be ap proximately the same and this is found to be the ca e Thermal detectors operating at room tempera ture have a lower limit of ensitivity of the order of 10^{-10} watt with re pon e times of the order of 0 1 sec This limit can be con iderably reduced if the detector is capable of operation at low tempera ture

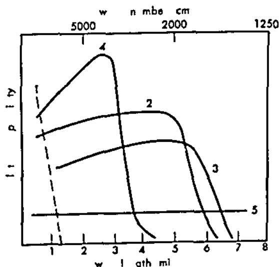


Fig 2 Spectral sensit ty of Inf ed d tector 1 Inf a ed sens t zed photog ophic em ls n; 2 PbTe (lead tellur de) photoco d ct e detect (efrig r at d); 3 PbSe (lead sele d) ph toconduct e d tector (refr ger ted); 4 PbS (lead s lfde) photo o d ct e detecto 5 thermal d tect r Respo si ty scale i ot the same for th a ous det ct rs b t the app o mate wa ele gths at wh ch det cto 1 2 3 a d 4 b come le s respo si e tha a th mal d te to a co ectly show

Propagation of infrared radiation The proper ties of various media for the transmi sion of in frared radiation are often quite different from those of light For example window glass is quite *opaque to* 5 μ radiation whereas pure germanium crystals which do not transmit vi ible radiation are very tran parent to this wavelength (apart from reflection losses which can l e reduced by ur face coatings)

The attenuation of infrared radiation by the atmosphere is of special interest Nitrogen oxygen and the rare ga es are transparent to all infrared wavelengths but water vapor and carbon dioxide are strongly absorbing in certain region In the range 0 8–4 0 μ there is irregular al orption due mainly to water vapor with more or le s open windows at al out 1 0 1 4 1 (2 2 and 3 4 4 0 μ From 4 to 8 μ water vapor and carb n dioxide together are strongly absorbing l ut there i an extensive window from 8 to 13 5 μ This window i of great meteorological importance l ecau e the peak of the radiation curve of the earth falls near 10 μ Beyond 14 out to 600 μ there is more or le s continuous al orption l y atmospheric water vapor arising from the rotational energy level of thi molecule

Liquid water is rather generally opaque in the infrared al ove 2 μ in path length larger than 1 mm The tran mi ion of infrared ra liation tl rough fog is little better than that f vi il le light l ecau e of a combination of cattering and al orption by the water dr p l t Th p *pular mi c nception* tl at fog is tran par nt t infrared radiati n has p r haps ari n fr m the well ad rti ed effect ene of red en iti e ph t grap hic f lm f r ph t grap hy tl rough atm pl eric l az of lu t particle

[R C L]

Bil liography R S F tey Infra re l new u for an ld te l niq i *Mes l s and Rock ts* 3(7) 107 11? 19 8 (R Harri on R C I rd and J R Loofl urow *Practical Sp t os op y* 1948 Infrared p l y ic and te l n l gy *I r e IRE* 47(9) 1413 1 00 1959 R A Smith F F J n and R P Ch mar *The D t ct on n l Mea u r m nt of Infra red Ra l ation* 19 7

Infrared radiation (biology)

Inf ared radiat on occupy the pan between the vi ible spectrum and rad o wa es encompa s ng w vele gths 7800–4 000 000 A ne ther boundary be g p e elv d l mited All bod es abo e absolute zer t mper tur a p te ti l sourc of nf a ed rad at the ef e all rgani ms are cont nually e p ed t th m Ab ut 60% f the r ys e i fra ed Water ab orbs nf ared rad t str gly except for th ba d of trans p te b tw en 7800 d 14 000 A Sin e protopl m c nta n m cl wate it ab o bs nf ared r d t read ly A larg a m l h rbs i fr red d at on t it urf c nly the p n fr m 7800 t 14 000 A penetrati g s fa as the blood ves els S INFR RED RADIATIO

Wh le m ny b t n and eve tis es selec t vely absorb nf a ed ray nd e might there f) e po t late s l ct e effect of the e rad ati n n ha e be nequ o ally dem nstrated exc pt po bly n onjunct n with x ray The rea on is pe hap be a e q nta of nfr r d rad ati n do not e ste ene gy t tes t m le ules th r than thos exc ted b o d cted h at S e X RAY(S) PHY ICAL NATURE OF

The e e t al b olog c l effect of infra ed rays d pe d p ima ily p n the r e t tempe at re produ ed f Il wi g the ab rption wh h i turn t e es th t f b log al ct tie p por t on to th t mpe atu l ange Becau e of the pr m n e of nf d nlight, rg m h w m y adaptat to d pate r to d th heat. Th t mp at r of a l rg a imal o pla t may ri t mpo rily but the h t i d pated by t an p at the pla t a d by pe pirat on in th a mal S bm g d an m l and pla ts ar pr tected by the w te the tempe at re ha ge of wh h depe d pon the h at apacity f the pa t l r body f wat

Tr tm nt f bi l g l m terial with nfr red d t n (800–11,500 A) e the b f re or ft x ray t tm t t r se th rr ng me t in h m som nd ed by th ay i t es f pl t d a mal te ted Th wa i wh h the nf a ed r d t n do th s i known b t c m p abl am t f co d t d he t does not ha th m ffect

Th m di l m n mak e of nf a ed d a t t tr t p t tra b r t p r pher l asc l d se se th ni mu l pa d m ny th pa n f r hi h h at ng gi el f p obably ber f od l t f per ph al v l F r th p rpo gl w l ad t r generally em pl yed but f som p) po es the m e pen tr t g d t n (7800–14 000 A) bta n bl f om n ndesc nt so a e p ferable to the gl w l t mulat ul t d p n the t ue

B RY I S THER IOTHERA Y [A C GI]

B I I g ph O CI r M d al Phy s l
l 1944 A H lla d (d) R d t B l gy
1 1 19 4

Infrared spectroscopy

The tudy f the propertie of materi l sy tem by me ns f the r interact on w th infrared rad ation d spersed i t a p ct um (see INFRARED RADIA TION) The i fr red reg on i valuable for tudy of the tr ctu e of matter l ecau the natural ibra t onal freq e c e of atom in m lecules and rys tal fall in the infrared range Some ga ous mole cules also have r tational frequen i s in the f r infrar d ange and c rta n frequenci s corre p n l ing to en gy l v ls of electr ns in sol d and larg m lecules c rre p nd to tho e of the n ar nfr red Fo d ta led di cu i n of molecular v bration and r tat on se MOLECULAR STRUCTURE AND SPECTRA

The infrared bso ption pectr m f a molecule s h ghly chara t r t c and often has been re f rred t as a molecular finger pr nt The pe t um n thu be u ed for molecular dentif cat on Be c u e the b o pt on of radiation at v rious in frared f equ n ies s q ant t ti ely related to the numbe of ab o bing m lec les in a sy tem quanti tati e analy i i al-o p s ble

Th usefulnes f n i fr red ab rpti n pe trum f ide t fi ati n and chemi al analy s was cogn z d s long ag as 1890 In the early 1900 the American phy c t W W Cobl ntz determ ned the infr red spectra of h ndreds of substa ces and learly dem n trated the p tenti l alue of such pectra U fortunately the in trun ent t n f th t d y a cumber m and nece ar ly h memad o that few phy ici ts and ch mi t w e attracted by Coblentz s w k Only aft r the development of c mme t l el ct n c d i es for mpl ficat o and r o d ng of a ont nuou ly sc nn d pectr m was ext n e u e made of th tech que Apart from refi em nt in in tr me tati n th infrared spect a f m le l s a e oft i d t d y in ba ic lly the am w y as th t u ed b Coblentz.

Instrumentation and techniques The usual r ng m nt f r mea ur me t of an nfra ed pec trum i hown ch mat all in F g I A ou c Q e ds a beam of co t n us nf a d radi t n to sphe al nd n ng m rr r C wh ch p sses the be m through S th sampl to b studi d Som f the i f ared fr quen i s i the beam a ab rb d tr gly me w kly Th r d c d b am pa e and com t f us at th ent nce lit of th mo hr m t r M The latte an inf red spe t mete wh h d spe s the radiation into a p trum One fr quency t a t me ppears at the ex t l t f M fr m wh h th d t n of that f equ ncy is p ed b a su table opt c l y t m to th d tect T Th d te t r (a therm oupl other de) co rt the rad ant energy into a electri al signal whi h i amplified electr c lly t A nd re rd d by ch rt e order CR

An i f a d pectrum s a reco d f ntensity of inf a d rad at on a a f n ti n of f equ ncy o w length T p oduc su h a r d the ch rt de d en in sy h ni m with th di

into quantum detectors, resonant detectors, and heat engines or thermal detectors. The first are devices which convert a quantum of the radiation in question into a proportionate signal by some process which is insensitive to quanta of less than a certain energy (*for example, the mean energy of* quanta emitted by a body at room temperature). Photographic emulsion, photoelectric cells, and Geiger counters are examples of quantum detectors. Resonant detectors are devices that are responsive only to radiation of the frequency to which they are tuned. Heat engines act as detectors by converting the radiation into heat and using the heat to operate a device that produces a signal that is proportionate to the amount of radiant energy received.

No resonant detectors have yet been constructed which can be tuned to infrared frequencies. For the photoelectric infrared (see the table), quantum detectors in the form of specially sensitized photographic emulsions, photoemissive cells, and particularly photoconductive cells are usable. As can be seen from Fig. 2, the responsivity of such detectors varies considerably with frequency and drops to low values at wave numbers of about 2000–3000 cm⁻¹ (3.5–5 μ in wavelength). Photoconductive detectors are known having good responsivity below 2000 cm⁻¹ (above 5 μ), but these must be operated at or near liquid helium temperatures (<10 K).

Therefore, in a large part of the infrared region heat engine detectors, whose responsivity is the same to all kinds of radiation provided the radiation is converted entirely to heat in the detector, are the only generally usable kind. Examples of heat engine detectors are thermocouples and thermopiles, which produce an emf when heated; bolometers, which change their electrical resistance when heated; and pneumatic radiometers, in which heat *is detected by the increase in pressure of a heated* gas. Because these devices are all subject to the laws of thermodynamics governing the conversion of heat into useful work (that is, into a signal), their ultimate responsivity is expected to be approximately the same, and this is found to be the case. Thermal detectors operating at room temperature have a lower limit of sensitivity of the order of 10^{-10} watt with response times of the order of 0.1 sec. This limit can be considerably reduced if the detector is capable of operation at low tempera*ture*.

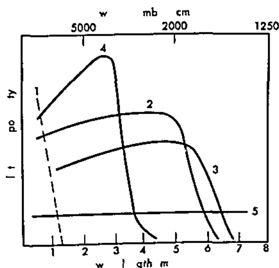


Fig. 2. Spectral sensitivity of infrared detectors: 1, Infrared-sensitized photographic emulsion; 2, PbTe (lead telluride) photoconductive detector (refrigerated); 3, PbS (lead selenide) photoconductive detector (refrigerated); 4, PbS (lead sulfide) photoconductive detector; 5, thermal detector. Responsivity scale is such that the same for the various detectors, but the approximate wavelengths at which detectors 1, 2, 3, and 4 become less responsive than a thermal detector are correctly shown.

Propagation of infrared radiation. The properties of various media for the transmission of infrared radiation are often quite different from those of light. For example, window glass is quite opaque to 5-μ radiation, whereas pure germanium crystals, which do not transmit visible radiation, are very transparent to this wavelength (apart from reflection losses, which can be reduced by surface coatings).

The attenuation of infrared radiation by the atmosphere is of special interest. Nitrogen, oxygen, and the rare gases are transparent to all infrared wavelengths, but water vapor and carbon dioxide are strongly absorbing in certain regions. In the range 0.8–4.0 μ there is irregular absorption due mainly to water vapor, with more or less open windows at about 1.0, 1.4, 1.6, 2.2, and 3.4–4.0 μ. From 4 to 8 μ water vapor and carbon dioxide together are strongly absorbing, but there is an extensive window from 8 to 13.5 μ. This window is of great meteorological importance because the peak of the radiation curve of the earth falls near *10 μ. Beyond 14 out to 600 μ there is more* or less continuous absorption by atmospheric water vapor arising from the rotational energy levels of this molecule.

Liquid water is rather generally opaque in the infrared above 2 μ in path length larger than 1 mm. The transmission of infrared radiation through fog is little better than that of visible light because of a combination of scattering and absorption by the water droplets. The popular misconception that fog is transparent to infrared radiation has perhaps arisen from the well-advertised effectiveness of red-sensitive photographic film for photography through atmospheric haze of dust particles.

[R.C.L.]

Bibliography: R. S. Estey, Infrared: new use for an old technique, *Missiles and Rockets*, 3(7):107–112, 1958; G. R. Harrison, R. C. Lord, and J. R. Loofbourow, *Practical Spectroscopy*, 1948; Infrared physics and technology, *Proc. IRE*, 47(9):1413–1700, 1959; R. A. Smith, F. F. Jones, and R. P. Chasmar, *The Detection and Measurement of Infra-red Radiation*, 1957.

Infrared radiation (biology)

Infr red rad at ons or py th sp n between the v bl spect um and rad waves ncompa ing w vel ngths 7800–4 000 000 A neitl er boundary be g prec ely delim ted All bod es abo e bso- l te zer in t mper tu e r pot ntial u ces of i f a ed rad at n th ref re ll organi m ar e ntin ally xpo ed to them About 60% f the su r ys a infra ed Water ab orb infrared radiat on tr ngly except f the band of trans- pa ncy betwee 800 d 14 000 A S nce p oto- pla m nt much wat r it ab orbs nf ared d at ead ly A la ge a mal ab o l s infrar d ad ati n at t s rf ce only the p fr m 7800 t 14 000 A pe trat ng as far s th bl od ssels S INFRAR D RADIATION

Wh le m y sub ta ces and even ti u l c t ly abso b frared r y and e m gl t the e- f e po t late f t ffects f the e r diat n n n h e been un q ocally dem nstr ted e c pt po ibly njun t on w th x r y The r a o is perh p be au e q anta f nfr red r d ti n do n t exc te e e gy t tes n m lecul s oth r than thos e c ted by cond t d he t S e X RAY(S) PHYSICAL N TURE OF

The e enti l bi log al ffect of i f ared ays d p nd p mar ly po the r e i tempe t re p od ed f ll wi g the ab o pt on wh h n t rn e se th rate f b l g cal ct ti s n pr p t t the temp tu e hange B u e of the p m e of nfra d u light rg ms sh w many d ptati s t d ip te i a d th h at The tempe t r f a l rg a mal plant may r se temp ar ly b t th heat i d ip ted by tr p t n th pl t and by pe p rat n n th n m l S bme ged n m l and plant a p tected by the wat the tempe ature h nge of wh h d pe d po the he t apac ty f the par t l body f wate

T eatm t f bi l g al m terial w th i f red ad t (800–11 500 A) the befor r ft r x a i atment ea es th a a g me t n h m m du ed b the y in ti es f pla t a d a im l tested Th w y n wh h the i f ed r d t n d th i u kn w b t a m pa all m t f c du ted he t doe t ha e th m ffect

Th med l ma mak f fr ed d r t t t p a n t a n bu r pe ipher l scul d se ses, tl ti m l p nd m ny tl pa n f h h h at g g es r l ef p bably bera f sod lat f periph r l el F th p rpos gl w l d t a e g n rally em pl ed l t f som p po es tl mo p net t g d t (7800–14 000 A) obta n ble f m desc t so es e p f ble to th gl w l t t m l r ul t de pe n th t ues S B sit r THERA THER PY [A C GI]

B I l g phy O Cl e M d l Ph s a l l 1944 A H ll d (ed) R d n B l g 1 1 19 4

Infrared spectroscopy

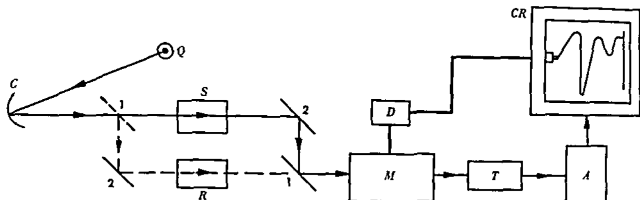
Th tudy f tl e p opert es of mat r al y tems by m ans of the r int ract on with i frared radiati n d p r ed nto a pectrum (se INFRARED RADIA TION) Th infra ed region is valuable for st idy of the str ture of matt r beca e the natural v bra ti nal fr quencies of atom in m lecules an l crys- tal fall in the nfrared ra ge Some ga eous m le- ules al o l e rotati nal fr quencies in the far inf ar d range a d certain fr quencie c rre pond ng t energy le els f electr ns in olids and large molecules c rre-po d t th e of tl e n ar i fr red F r a d t l d di cu i n f molecular brati n a d otation se MOLECULAR STRUCTURE AND SPECTRA

Th i frared ab orption spectrum of a molecule is h ghly har cteristic and often ha been re f r ed t as a molecular fing r print Tl e pectrum a thus b u ed f r m lec l r id ntific ti n Be- au e th ab rpti n of radiat on at ari us in fr r d fr q en es quantitati ely related to the umbe of ab rb ng molecules n y tem q anti tati e naly is i al o po s bl

Th usefulness of an nfra ed ab orption spec trum fo identifi ati n and chem al analys s was r c gniz d a l ng go a 1890 I the ea ly 1900 th Am r an phy c t W W Coblentz determin d the infrared spectra f hu d ed f ub tan e and clearly demon trated th potent al alue of uch spectra Unfortunately tl e i t umentati n of that d y was cumber m and nece ar ly homemade th t few phy c ts and chem ts we e attra ted by Coblentz s w k Only afte the development f c mmer ial el tron c de ices for ampl ficat n and e ding of nt n u ly nned pectrum was ext n e e m de f the techn qu Apart f om refi me t i st m nt tion th inf ared pe tra f mol ul s e obta n d tod y n ba lly the ame wa tl t u ed by Coble tz.

Instrumentation and techniques Th al a an m nt f r measu em nt of an infrar d tec trum i hown hem t c ll in F I A ou Q send be m f c ntinu us infrar d radi t on t a sph ri al c nde g m rr r C which passes th b am th gh S th mple t be tud ed S me f th inf red frequen e in th beam ab- orbed tro gl some w akly The educed b m pa es n and c m s t a f u at th entra ce lit of th r on l m i r M Th latte is an i f ared p ctr m ter wh h d per e the radi ti n int a sp ctrum One f q e cy t t me ai pears at the ex t slit f M f m wh ch th ad at of that f qu ncy i p ed b a t ble pt al tem to th detect T The det t (a th rm pl o ther des) c n ert the r d t energy into an elect i al signal wh ch i amplified ele tron lly t A nd rec d d by a chart r d r CR

An f a ed p trum s a cord of ten ty of f a d r d at on as a functi n f frequen y o wa le gth To p od ce u h a reco d th ch rt r ord dri ynchr n ri w th th dis-



Fg 1 D ag am of a record g infrared spectromete

persing system of the monochromator M by some common driving mechanism D In this way a given position on the chart corresponds directly to a given frequency setting of M at which setting radiation of that frequency is emerging from M

For many basic reasons—atmospheric ab orp tion variation of source intensity with frequency changing dispersion in the spectrometer and the like—the electrical output of the detector would not be con tant even if the sample S were com pletely transparent To correct for these variations it is necessary to determine two spectra one with the sample S in the beam and one with S removed from the beam The absorption of S as a function of frequency can then be computed from these two spectra The indi idual spectra on which the com putation is based are called single beam spectra

The computation is laborious time consuming and potentially unreliable because of changes in the entire system between the two determinations of pectra The e difficulties are avoided if a second optical path shown in dotted lines in Fig 1 is introduced The second optical path called the reference beam is made as nearly like the first as possible except for the absence of the sample In fact the reference beam may contain an ab orption cell R which differs from S only in the ab ence of the sample itself For instance if the sample S were in solution R would contain the same amount of sol ent as S

The operation of the double beam spectrometer often called a spectrophotometer consi ts of a rapid switching of the beam (say 10 times per econd) back and forth between S and R by alter nately placing plane mirrors 1 and 1 in the optical ystem The identical mirrors 2 and 2 are perma nently placed The pectrum is scanned continu ously as for ingle beam operation but the beams through S and R are compared 10 times per econd and the chart records the energy passing through S relative to that th ough R In this way the ariations mentioned ca cel out

Typical spectra Typical infrared pectra plotted automatically as per ce t t an mi ion of the ample on a linear frequency scale (wave number in cm) are hown in Fig 2 Samples of ga e liquids and olids can be read ly measured Techniques for high and low temperature of ample and for small samples (down to about 1 mg or le s in special cases) are in common u e

Per cent transmission T the quantity u ually plotted by commercial instruments is defined as

$$T = 100\ I\ /I_0$$

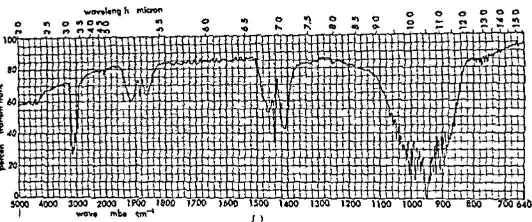
Here I_0 is the intensity of infrared radiation of frequency ν entering the sample and I is the in tensity of the same radiation after passing through the sample The per cent transmission T at fre quency ν is different in principle at different values of A quantity of fundamental importance the absorbance A_ν is

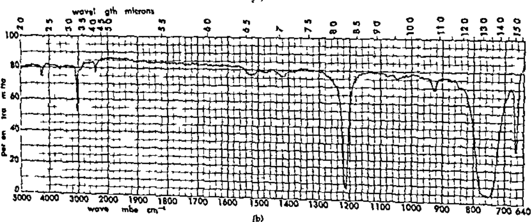
$$A = \log\ (I\quad /I\ ) = -\log\ (T\ /100)$$

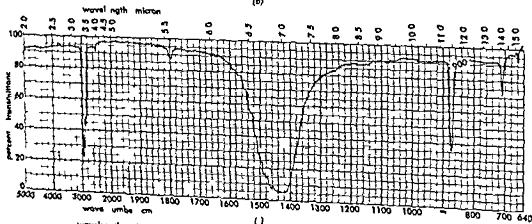
The absorbance A is proportional to the number of absorbing molecules and by evaluating the proportionality constant at frequency ν for a gi en kind of molecule in a particular system the number of such molecules in other systems of the ame kind may be measured quantitati ely

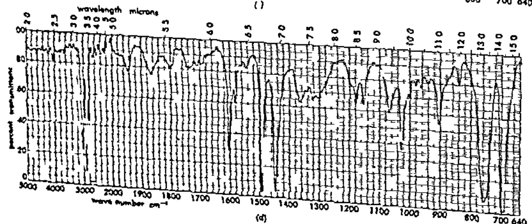
Applications An infrared spectrum consi ts of a plot of T or A as a function of (or of wa e length λ) The basic information provided by the spectrum is a set of values at which the ul tance is absorbing strongly that is at which T is a mini mum (Fig 2) or A is a maximum The e fre quencies of maximum absorption usually corre spond to the actual ibrational frequencies of the absorbing molecules or to some arithmetical combi nation of such vibrati nal frequencies If the mole cules are in the vapor pha e absorption maxima

Fg 2 Typ cal nf a d t a m sio spectra co ded a t mat c lly Not comp e ed scale o left port on of absc a (a) Sp ct m f thyle ga T sm s o m ma a g 850–1050 cm r ult f om mod l t on of thyle b at o al f q cy at 950 cm by molec l tat o al f eq e s (b) Sp ctrum of l q u d chlo f m (c) Sp ct m of powde d cryst ll calc m ca b ate Powder w u p d d i m e l o l t obt pectr m T m n m im m at 1430 cm ch act t c of ca bo ate io that at 2900 cm of CH g o p l the o l (d) Spe t m f a amo ph s h gh polym (p ly ty e e) D ta l he e sh ws why f ed pect a a som t m oll d m lecul f g p t


waveleng h micron
percen transm ttanc
wave mbe cm⁻¹
( )


wavel gth microns
per en tra m ttanc
wave mbe cm⁻¹
(b)


wavel ngth micron
percent transmittanc
wave umbe cm
( )


wavelength microns
percent transmittanc
wave number cm⁻¹
(d)

may also be observed at frequencies which are combinations of frequencies of molecular rotation and vibration. The qualitative usefulness of an infrared spectrum lies in the fact that the set of observed vibrational frequencies characterizes the absorbing molecule.

Qualitative chemical analysis. Infrared spectra can be used for the following purposes:

1. To identify pure chemical compounds by comparison of the spectrum of an unknown with previously recorded spectra of pure compounds. Catalogs of spectra are available, and in addition there are practical methods for storing the information in the spectra on punched cards which can then be used for fast comparison of unknown and known spectra.

2. To identify the constituents of simple mixtures when the spectra of the possible constituents are known.

3. To show the presence of a group of atoms, a so-called functional group, in a molecule of unknown or doubtful structure. It has been known since the 1890s that certain groups of atoms—for example, a methyl group (CH_3), a carbonyl group (CO), a nitrate ion (NO_3^-)—have characteristic absorption frequencies that are relatively independent of the rest of the molecule or crystal in which the group occurs. Literally hundreds of such group frequencies are known.

Quantitative chemical analysis. There is a quantitative relationship between absorbance and the number of absorbing molecules; thus the quantitative analysis of mixtures by infrared means is feasible. It is also possible to determine how much of a functional group is present in a mixture or in an impure substance, though limitations are set on this procedure by variations in functional group absorbance. The infrared method is not particularly sensitive, the ultimate limit in detection and measurement of minor constituents being in the range 0.1–1.0% except in unusually favorable cases. Precision of measurement is often as good as 1% of the quantity being measured but may be considerably worse. Infrared methods are especially useful in determination of isomeric substances and in measurement of constituents of a chemical equilibrium.

Determination of molecular structure. Structures of molecules can be determined to varying degrees of refinement from infrared spectra. If only a few independent parameters (interatomic distances and bond angles) are required to specify the structure, as is the case with a small symmetrical molecule, these can be evaluated from the moments of inertia of the molecule, which can in turn be measured from rotational frequencies usually observed as fine structure in a vibrational absorption. The structural parameters of carbon dioxide, methane, ethylene (see Fig. 2a), and ethane, for example, have been evaluated with high precision from their infrared spectra.

If the number of parameters is too large to be determined in this way, it may nevertheless be possible to draw conclusions about the molecule's shape without measuring its size. The number of vibrational frequencies which appear in the infrared spectrum is related to the molecular symmetry, and it is often possible to infer the symmetry from the observed spectrum. Such inferences are more reliable if they are based on combined data from both infrared and Raman spectra. See RAMAN EFFECT.

It is still possible to say something about the structure of large molecules of little or no symmetry from their spectra if one is content with a statement about the presence or absence of various functional groups. The organic chemist often finds such statements very valuable. The nature of functional groups in the molecules of high polymers or of natural products such as the steroids can be determined from their infrared spectra, and this permits information about their structure to be obtained.

Study of the solid state. The infrared spectra of solids give information about modes of vibration of crystal lattices, about hydrogen bond vibrations in crystals held together by such bonds, and about electronic energy levels in semiconductors and superconductors. Hence infrared spectrometers are often used by solid state physicists, and increased use of infrared methods in this field can be expected, especially as techniques for the spectral region 10–200 cm^{-1} become more widely available. See SPECTROSCOPY. [R.C.L.]

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Inhibitor (chemical)

A substance which is capable of stopping or retarding a chemical reaction. To be technically useful, such compounds must be effective in low concentrations, usually under 1%. The type of reaction which is most easily inhibited is the free radical chain reaction. The study of inhibitor action is often used as a diagnostic test for free radical chain character of a reaction. Vinyl polymerization and autoxidation are two important examples of the class. Another reaction type for which inhibitors have been found is corrosion, particularly in aqueous systems. The economic importance of corrosion inhibition can scarcely be overestimated. An understanding of inhibitor action depends on an understanding of the processes which are to be interrupted.

Inhibition of vinyl polymerization. This type of inhibitor action must be considered in terms of the accepted mechanism for the polymerization process, which may be summarized as

$$\left.\begin{array}{l} P \rightarrow R \\ R + M \rightarrow \sim\!\sim M \end{array}\right\} \text{in tiat n}$$

$$\sim\!\sim M + M \rightarrow \sim\!\sim M \quad \text{propagat on}$$

$$2\sim\!\sim M \rightarrow \text{t rm tio by d me ization r d p opo t onat n}$$

wh re P is a c taly t, often a pero id R is a f ee rad cal deri ed f m th catalyst M is a m n m r nd ~~M a gr wing p lyme ch i Th pol mer zation will be t pped nh b ted f som add d h tan e (an inhibit r) rea ts m r *e d ly th n d* th m n me with R to y ld p od ct which w ll not ta n the p ly m izat F ery eact on chain s t pped until the i hib t r s c n umed If the added sub tan e (*tard) is some h t les r a ti the m* me e n mpet more successfully fo the in ti t ng rad al so th t tl e esult i etardat n ath r than total i h bition The d ffer nce b t een inh b t n and et dat *n i one of degre* rather than of kind

Phe ol c e mp ds and qu n s The e i t r a t w th an nit at ng rad c l or w th a gr wing p lym r h ther by hydr ge tom *b trac* t n or by r d al add tion t an u satur ted l nk age

~~M + O=C₆H₄=O → ~~M_H + HO–C₆H₄–O· ; ~~M–(quinone) → ~~M–(hydroquinone, OH) ; → ~~M–O–C₆H₄–O·

Tl ph n y ad c l p od ed ar tal lized by reso nd r n t suff c ently ea t ve t add t th yl l nkag I n th m nome m lecule The l f te of the rad al fu tl h dro g nat m lo by r a t n with sec d pol m r d l r b d p y t at w th another phe n y ad l t y ld qu n ne a d a hyd q i n b th f whi h may ntinue t a t as i hib t All th r a t n p s b l ties sho n ha e been d m tr ted xpe m ntall Alth gh the eff ien ies f ph l and qu nes f th te rup t n f pol m zat n ary subst ntially w th th t iu f thes m lecules they may be la sed nh b t r A mat am n r act n a m lar m n

N t omat A typ fied by tri tr benze e tro m t fu t n a *retard* rathe than as nh l t r n m t polymer zat n It s neces ary h wes t n d r the pecific r a t n in ol ed Th pol n t a m t s nh b t th polym r za t f yl tate t rd th t of sty n a d have n effe t on that of methyl methacrylate No clea -cut mecha m ha been e tabli hed for the interact on f nitro c mpound with free rad c ls

M mers Both m nome and the rad cals d r ed from them d ffe greatly am ng them el e in re ct ty Thus although certain m nomers may c p lymerize with one an ther othe s may actu *ally function as inh b t s* Styrene and vinyl ace tate for e ample each polymerize well when alone Styrene h we er inhibit the p lymeriza ti n of inyl acetate This ccur becau e the v nyl cetate rad cal and the tyren m nome are highly rea t wherea the tyre rad cal and tl e *nyl acetate monome are n t* A m ll am unt of ty ne added to v nyl acetate w'll rap dly re act w th a y inyl acetate r dicals formed when polymerizat on is n t ated The re ulti g t ene-l ke rad c l w ll ea t only very slowly with the v nyl ac t t mon m r In the o er all p ce s the l a n ca rying radical i con erted to one which is too un a t e to carry on the cha n

Autoi hib t on This act on om t mes called al lyl c termination is xhibited by m nomer wh ch ntain the h ghly rea t allyl c C—H linkage F e rad cal ar c p bl of hy l gen atom ab-stract n f om copresent mole ule a well a of add t on t an uns t rat d linkage The ea with whi h th s ab tract on r a t on is c r ied t by a g en radi al is a fun t o f the rea t ity of the C—H l nk ge which attacked Th rea tiv ty of radi als conta ni g these C—H l nkages *incr a es* in the rde aryl < primary alkyl < second ry alkyl < te tiary lkyl < allyl < benzyl Becau e of thi h gh r ct v ty a m nomer co ta nin an *allyl c C—H allyl a etate fo e mple fu ctions* s its own retarde

$$\sim\!\sim M + CH_2{=}CHCH_2OAc$$

$$\swarrow \qquad \searrow$$

$$\sim\!\sim MCH_2CHCH_2OA \qquad \sim\!\sim MH + CH_2{=}CHCHOAc$$

The re ona ce tab l zed allyl c rad c l w ll act w th the m nom r o ly ery sl wly The pr d mi nt further r ct o i d me izatio N t only i p lymer *zat on* lowed i thi a but the mol u l we gl t f the polym r f *rmed* i l w

Misc lla ous i h b t s O ygen dine and n tri ox de i tera t rap dly w th f e rad cals to y eld tabl p d t In lusi of these materials in polyme izi g syst m th s l ad to ffect v in hib ti n It f part ular nterest that xygen w ll c pol me i e und carefully co t olled con d t w th ce t n m n me s tyre for exam pl to yield h gh molecular we ght polymer c per x des The r pe ting nit is

$$[-CH(C_6H_5)CH_2OO-]$$

Iod ne and n tric o de ha e been used t s v ly to detect a d in om ca s t d ntify alkyl f ee d l in no ch n a well a ha n rea t ns Thi method has p o ed t be of gre t al e n de fin ng p mary p oces es in photoch mi al decom *pos t n of ld hydes a d ketones*

Inhibition of corrosion Metallic corrosion in conducting media is electrochemical in nature Local electrolytic cells are set up because of the presence of impurities crystal lattice imperfections or strains within the metal surface The result is dissolution of the metal from the anodic regions Corrosion inhibitors now in use may operate at the anodes or the cathodes or provide physical protection over the entire surface

Anodic inhibitors These are mild oxidants which reduce the open circuit potential difference between local anodes and cathodes and increase the polarization of the former Sodium chromate and sodium nitrite are most commonly used The former is used in air conditioners refrigeration systems automobile radiators power plant condensers and similar equipment Sodium nitrite finds special use in the protection of petroleum pipelines It is effective even on rusty mild steel An extension of the nitrite type is the use of nitrite salts of secondary amines as vapor phase inhibitors The inclusion of a salt such as dicyclohexyl ammonium nitrite with a packaged steel object provides effective protection against corrosion

Cathodic inhibitors Compounds such as calcium bicarbonate and sodium phosphate in an aqueous medium deposit films on metal surfaces which provide physical protection against corrosive attack

Organic inhibitors These are usually long chain aliphatic acids and the soaps which are derived from them Adsorption of these compounds on metal surfaces gives a hydrophobic film which protects the metal from corrosion by many agents As little as 0 1% of palmitic acid for example is sufficient to protect mild steel from attack by nitric acid *See* ANTIOXIDANT CATALYSIS CORROSION FREE RADICAL POLYMERIZATION [F H S]

Ink

A substance used for writing marking drawing and printing which is transferred by several methods to a wide variety of surfaces such as metal fabrics wood glass or plastics Inks consist of a vehicle or carrying agent and a colorant that is evenly dispersed throughout the vehicle In the United States inks are produced to the value of $300 000 000 annually

Writing inks *Writing inks are known to have* been used as early as 2000 B C For many years they were made from tannins and galls obtained from bark or nuts but with the spread of literacy their varieties increased Even inks used for typewriter ribbons may be considered as a special form for writing Modern writing inks are composed chiefly of aqueous solutions supplemented with gums or glues and dye colorants to which small quantities of pigments may be added The writing ink industry is distinct from other classes of ink manufacture

In the modern office duplicating machines are in common use Technically they are not writing machines yet they do use ink specially suited for each particular class of machine Proper inks are usually supplied by the maker or distributor of the machines

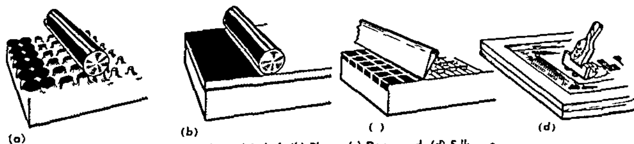
Marking inks These are the successors of man s efforts to make his mark with any medium available In shipping departments of industry and elsewhere inks are used with rubber stamp stencils, or special brushes to mark a great variety of surfaces of wood metal and fabric There are many varieties from liquid to solid which may be composed of a water alcohol oil or wax vehicle with either dye or pigment colorants

Printing inks Printing inks are used on printing machines from the small job press to large high speed multicolor presses which produce printed matter in great volume and variety with four printing systems to transfer thousands of types of ink onto hundreds of different types of surfaces.

For instance a book may be bound in cloth cover using a bookbinder s ink printed on a platen press it may have illustrations printed with process inks on a cylinder press and bound with the text pages or on a slip cover The text or reading matter may be a book class of paper and run on a rotary press with a book ink Such combinations are not unusual Inks may be labeled with different names designating either the class of ink or the end use

There are four distinct printing systems for transferring ink to paper or other surfaces (1) letter press or relief printing in which the type or illustrations are above the surface to receive the ink from distributing rollers (2) lithography in which ink is transferred from a level or plane surface (3) intaglio in which ink is transferred from a depressed surface (includes rotogravure gravure copperplate printing steel die embossing and metal etchings) and (4) silk screen in which a *roller squeezes ink through a piece of silk stretched* on a frame to paper or card underneath the frame (Fig 1) *See* PRINTING PLATE

Each system requires different inks for different presses and papers but the printing ink industry is generally a custom prescription one This re



tem for k t sfe (a) Rel f (b) Plane (c) Dep d (d) S lk e

qu res a f rmula made f r th partı ular tra sfer methods v hicles adapted f r press operatio nd pigm t color nt co d ng to th ır end u e The formula ı refully reco d d by we ght of the ı gred ent a d ı g n number R peat rder for add t on l or lat r ru mu t be exa t t the mall est tolera c espe ally for u n label and pack ag p int ng

Printing ink vehicles The p ınting ınk form la *f r the eh cle w ll be pr pared to suit th follow* ı g c nd t (1) the p ı t ng sy t m u ed (2) *th cla* nd speed of the press (3) th dry ng process r q ı ed (x dat o penetrat on evapora t on o g lat on o p p t on) (4) the class nd t xtu e of tl u f ce to be printed (5) the at f the ı gment r q ı ed d (6) any pe ı l f nct o f the p nted m tte which may p- pl ı *both eh cle and p gment.*

The m ı ehı les sed are mı e al o l h at bod ed l n eed va hes with e n tenı es fr m \ 5/0 (ery thı l to No 9 (v ry ıscou lık st cky m l ses) h naw d c tton eed or p rılla l al oh l glyc ls and hyd oc rb n s l ents These a d othe m y be u ed s ngly or m de ınto mı tu es by the add t on f drı rs esins, gums r th r ld tı es to pro ıde good w k ng qualı t es on the pr s Addıt es r u ed t *mp o fin* ı h, h d e fl xıb l ty f th k f lm V rn h ı gred ent may b prep ed by d s l ng ook g mıx g or dı per ı n r by runnıng them to- g th thr ugh a nk *mill* Sp c alt e e pur h sed by the k m ke f m t de upplı r

Colorants Th nk film ı very thin (bo t 0 0001 ı) T nsp r cy s as eces ary f r some p po es pac t f r th rs The same film w ll ch nge ı lo pp a n when sed n d f *le* nt u f ces su h s book and ated pape s bec *e* f th l ght sc tt rıng of u f t xtu e l ght penet t n t th fiber or rı t on ı the h t nes f th h t

P gme t manuf ctu a mpl ated ch m l nd t y wh h s ppl es mo t p nt g ınk color ı fk th g nı and rganıc *p gm nts a e* sed P gm nts f a ı t ol w ll d ff r ı n m f th foll w ng w y pa t cl ze wetta b l ty pec fi gr ty pa ty olo trength dry ı g t m ı d ff e t h le a d es t n e t t t k f m l ght b t alkal a ıd gr ses fat a d wa

B k p gm nt bon bla k nd t g t d n ty blue v ol t t m b ed Am g th wh t p gment t ta ı m d de s sed f hı k s d bl c fi e al m na hy d t ıı des nd k l n d f e tenl ra

Th sam f m ly f p gm t m y be prod ced t es l h des Chrom y ll w run f m p m tone n th g n d t g lden n th red ıde Ch f f m l es ed —l th l ı l d es ıu g t tes m l bd tes y ll w —ch m s, Ha a, ben f bl ı n l lu M l r refl x pl th locya pe ek g een—phth locya r mı t e f ll w d l l *d* p ples—phthalocy n ne m ı r l red d l lu

All pigment must be thoroughly d per d and r finely m ll d on roller mill colloıd mill or b ll mills to pre ent reagglomerat on See Dye Pigment

Special ınks New ınks are u ed f r printıng on n wspr nt pape s New black for met op lıtan dailies ı a thın l qu d ınk f eque tly delı e ed by tank truck and pumped nto torage tank f om whı h ıt ı pumped to the p e s For the we kly *newspaper with smaller pres es* a l ghtly th cker on ı tency s u ed th s m y be del ered ın kıts o drums Blacks are made with mineral ıl and carbon black a d dry by p netrat on

The e of new pape col r h s ı c ea d very ap dly a t end wh ch will c ntinue Inks u d re n med *ru of pres* (ROP) *olo* Comic colors de ıgn te ınks u ed t print the comı upplements of new paper a well as comıc booklets usually n spec al pres es Their properties are ımilar to tho *e f news black*

Bookbı ders ınk used f r p ınt ng cloth r pl stı *book cov r re* heavy ı cou ınks made fr m lı seed o synthet c varnı hes Th y dry by *oxidation*

Co er nks are the opaque ı ks *u ed for* prı tıng o *colo* d p pers

Th c lors u ed fo three o four olor ıllust a tıo s known as pr cess ı ks may be used on all print ng y tems. Col rs select d are r d yellow and blue which when p ope ly run pp a to re produ e th tire chromatic spectr m

Metallic nks ar c mp ed f a speci l a m h nto which a e m ed fi ly flaked l m um pow *d r to represe t s l e* a d c mb nat ons f b s a d pp r fl ke *to e* mbl g ld

He t set ınks nam d for a dry ng method are c mpo ed f pec al f act s of mineral l with synthet c res s wh ch r main stable at r m t m pe atu e but evap rate r *pıdly* w h n run over a he t ng nıt tt l ed to the press at temperatu es of about 1500 F They are s ted for large editı ns f m gaz s a d catal g

M ıstu e et ınk d p nd on an the drying p oc e They h ve eh les of gly ols and alcohol solu bl resın which pr ıp t te the p gment con t t with *moistur* The r hief u e ı on wrapp ngs a d packages whe f ed *m* f om dry g od r ı mportant

Fl xog aph c nk (f rm ly named a lı e ınks) ed n pe l p es e w th rubber printing plates They a e b ng ed n r s *ngly e p c* lly f p ck g w apping u h a *fo l* t a pa e t pl stı *film* r p p r b g ma h nes Th y are omp ed of l oh l h *ll* r othe olatıle ol ents a d now c nta n p gment c l a t They are lıqu d ı n tency and dry by ev p tion

M gn tı nk a e a new typ *of* k now r e t g atte t n f u e on ort ng w th el ctronic eq pme t

Lithographic ınks l th graphy was ın nted by Al ı Se l ld *ın the e* ghteenth ce tury a d ha h wn great p g e s n e 1900 be au e of the ın t oduct n f the t ry ff t p e and the appl atı n of phot gr phy n th m k

system has great versatility for use on financial printing such as stock certificates bond and checks It is used for advertising matter displays billboards fine art reproduction greeting cards packages and metal decorating The inks used are of heavy viscosity made chiefly from linseed oil varnishes or combination of mineral or other oils with synthetic resins and pigments that are resistant to water They dry mostly by oxidation In the tin decorating industry for containers and signs the drying process is speeded up by the application of heat and the ink film requires greater flexibility

Offset inks are lithographic inks used on a press which transfers the ink first to a rubber blanket and then to the printing surface

Dry offset is a relief variant of the offset system The plate used is given an etch which produces a slightly raised surface The ink is run on an offset press without water This process is used frequently on check backgrounds or sales slips for protective purposes against the use of ink eradicators or erasers

Intaglio inks Intaglio is the printing system in which the image is depressed below the surface There are four classes rotogravure gravure die stamping and copperplate Rotogravure is used extensively for newspaper supplements catalogs and packaging

Rotogravure inks are liquids that are filled into tiny wells (as many as 40 000 per square inch) etched on a plate or cylinder A scraper blade removes the surplus ink from the surface and the ink is transferred to the paper drying by evaporation The vehicles are chiefly hydrocarbon solvent and alcohol

Copperplate inks and die stamping inks used for personal and business stationery are buttery pastes in consistency Both require special varnish properties for their use Because the plates are cut much deeper the film of ink transferred is much thicker

Silk screen system The silk screen process is well adapted for display card advertising but has

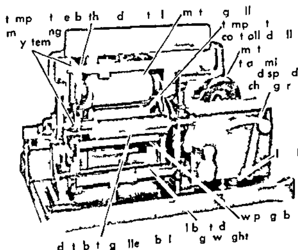


Fig 2 An Inkometer (Thwing Albert Instrument Co)

many other uses When fluorescent pigments are used brilliant colors are obtained The process is slow but mechanization is increasing for longer runs A piece of silk is stretched onto a frame The nonprinting areas are blocked out and the ink is squeezed through the silk with a roller to the paper or card underneath The inks are of buttery consistency with a film of good thickness which dries by oxidation

Manufacture Printing ink manufacturers maintain their own laboratories staffed by chemists and color matchers for formula development production control and testing One of the instruments for testing the tackiness of ink for press qualities is the Inkometer (Fig 2)

A Printing Ink Research Bureau is operated at Lehigh University Bethlehem Pa and is supported by the National Association of Printing Ink Makers New York *See* PRINTING [C.R.C.]

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Inland waterways transportation

Nearly 9% of the national intercity freight tonnage moves over the 29 000 miles of navigable inland waterways in the United States This system of natural and improved rivers and man made canals is the most extensive highly developed and efficient in the world The equipment used in the towing trade is modern specialized highly refined and includes powerful towboats barges of all sorts and the latest in navigational aids The largest tonnages travel over the Midwestern network of rivers but substantial volumes of bulk cargo also move in the East and Far West

Generally speaking inland waterways transportation is lower in cost than any other mode of transportation except pipeline

Many American methods of large volume towing are now being practiced in other countries where water transport always of key importance had never handled such great quantities of cargo with such powerful and labor saving marine equipment

Commodities moved Coal petroleum products sand and gravel and grain are the principal commodities handled on the American inland waterways system but many other products are also moved on the river in large quantities Most important among the newer cargoes are a vast variety of chemicals moving in specially designed tank barges This increase in chemical tonnage has taken up much of the slack created by the switch of many petroleum products to pipeline for transportation

Smaller lots of cargo less than a barge load comprise only a small portion of the total tonnage moved although several towing concerns in the

Fg 1 Fd 1B g t U t d St t the wo ld m t p werf l t wb t The bo t w s bu lt by th St L Sh pb ld g & Ste l C d p w d by f d f g d f p g t t l f 8500 hp

Ea t part ula ly dev te a great porti n of th b n t packaged bulk hipme t

The t da d r er b rge l ad u s in the ne h borhood f 1200 t n n a ba g 195 ft l ng by 35 ft wid w th l aded d aft f 9 ft The ba ges e d gned to fit th ee l ng by th ee w de t a tand d 600-ft by 110-ft ri r lock

O th M dwe t rn sy tem of rs many s h b ges a e la hed t g th r int h g t ws p h d f y h fty d el t wboats Th mo t pow rf l tow bo t fl at n 19 9 w th 8500-hp F deral B rge Li es In M V *Un t d Stat* (F g 1) wl h ca h e 40 m r l ad d b rge on the pen t f tl Lo M pp b tween St L u d N w O l n at pe d of o er 7 mph Su h a t w m ght ve m e th 7 c es be r th rd f mil l g c ry m h l ight a 1000 ail ad about f ur a erag oc n fre ghter a d y t m v through a arrow d metimes d g 9-ft de p han l 24 h r a day in an k d f th (F g 2)

In th Ea t and Fa W t mall r load ar e q ed l ecau l d ff re t pe at ng nd t n Most f th x a g pec ally n p n wate mos l p ll t w ng n wl h co t n l tugboat pulls one barge or a string of ba ge on trong law e S me pu h towing is u ed in the Ea t (on the N w Y rk St t Barge Canal and tl e Atl ntic Intr coa tal Waterway for example) but u ually it moves o ly one b rg at a time be au e of se e lock and chann l l mitations Haw er t w ng is tr d t onal th o gh t tl e w ld and only in the 19 0 d d oth r nation (n tably France G m y d Ven uel) begin using the more ef fic ent p sh tow ng method on a lim ted but highl u f l basis

Great Lakes By C a t Gua d defin t n C e t Lakes shipp ng is n t a f rm of inland waterways t a po t t n. Howe er the t nn ge m ved o er th Lakes yst m i alm t equ l to the total mo ed n the i land wate way Mo t Gre t Lakes t nnage n ts of o e m ved in large (up t 700-ft) f ei hte s F r addit onal informati n *see* SHIP MERCHANT

Navigation projects The inland waterways of th Un ted State re ma ntained at spe ified d pth by th U S Army Corps of Eng neers The Co ps al o exe c es s p rvi ry a tho ty o er new river onst u ti n p ojects I f cal year 1959 Cong es app priated o e $800 000 000 fo ri e nd ha bo s imp ovem t a d for recurring water w ys mai te an e Thus um was allotted not only fo mme ci l na g tion but also for flood con trol irr gati n hyd oelect c power pr jects on erv t on d ec e t n l l at ng

The majo w terway pr ject of th Federal go ernme t in ol e the c al zat on of exi ting i e Thr ugh s e of dams th proce cr ates sl ckwater pool along a er wh h c th be eas ly na ated ma ntai d to p pe depths a d nt oll d t el minate flood hazard Th b ge t projects nd rway in 19 9 wer as f llow

1 The Ohio Ri r whe e the xist ng 49 d ms w e to b replaced with 19 high dam and th

Fig 2 F d l Ba g L e U t d St t hown St L p h g t w of 42 b g Th hug t w north f Che ll b d p the M ppi R e t w pp mat ly 7½ n a

locks to be increased from 600 ft to 1200 ft in length

2 The Columbia and Snake rivers which when development is completed will be navigable to Lewiston Idaho and studded with huge multipurpose dams

3 The Missouri River which was to be fully canalized and raised from a 5 ft minimum depth to the standard Midwe tern 9 ft minimum depth

4 The Illinois Waterway where locks were to be made two way to ease current congestion and accommodate additional traffic generated by the opening of the St Lawrence Seaway

5 The Warrior Tombigbee Waterway in Alabama where lock capacity was to be increased

6 The Trinity River in Texas which was to be canalized to create a 9 ft channel from the Gulf Intracoastal Canal as far inland as the Dallas area

The rena cence of the inland waterways as the heavy haulers of industry is a fairly recent phenomenon in American history In the early part of the twentieth century river traffic was almo t elimi*nated by railroad competition However in the* 1920s as government canalization programs progre ed and new machinery (particularly diesel engines) and new equipment found their place on riverboats the industry revived and has been growing in importance ever since (see Fig 3)

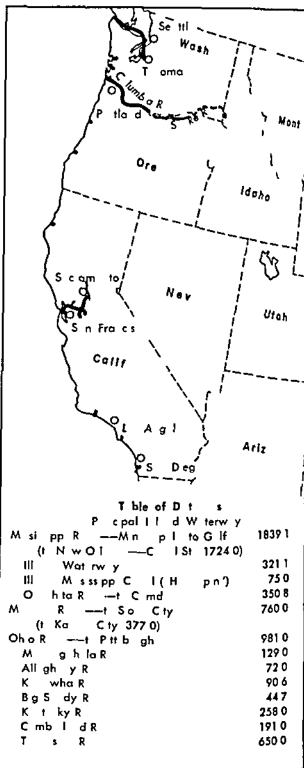
Machinery and equipment Prime mover of the inland waterway boats is the marine diesel engine equipped with a reverse reduction gear This gear enables the diesel to operate at maximum high rpm efficiency while turning the propeller at its far *slower but most efficient speed See* MARINE ENGINE

The riverboats of the Midwest are basically rectangular in shape some as long as 200 ft and are characterized by heavy pushing knees (vertical pushing braces) forward and propellers enca ed in Kort nozzles aft The Kort nozzle basically a funnel like cylinder surrounding the propeller can increase the propeller thrust by as much as 40% in certain cases *See* PROPELLER MARINE

Towing in Eastern and Far Western waters is *handled largely by conventional tugboats smaller* in length and beam than the riverboats and built with stem type bows molded hulls and rounded sterns

River barges fall into three categories—open hopper covered hopper and tank barge The e are designed respecti ely to handle weather resistant hard goods vulnerable cargo and liquid products

Originally almost all barges were de igned with a rake (o erhang) fore and aft and this is still the most efficient design when barges are towed singly *Howe er as* large fleeted movements of barge be came common on the ri ers many new barges were constructed as integrated or semi integrated es els The e are de igned for high towing efficiency in tows of many barges *An integrated* tow will ha e one lead raked barge with a quare stern a number of square bow and quare- tern barge and finally a trailing barge with a raked tern This type of



T ble of D t s
P c pal I l d W terw y

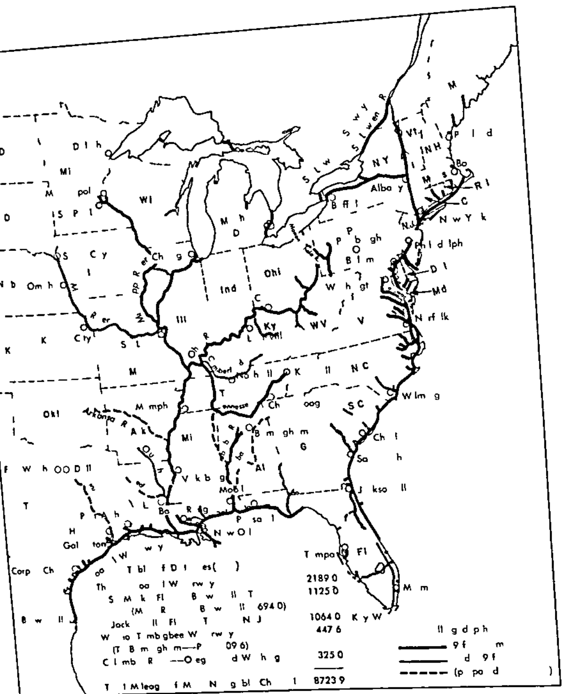
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Ill Wat rw y	321 1
Ill M s ss pp C l (H p n')	75 0
O h ta R —t C md	350 8
M R —t S o C ty	760 0
(t Ka C ty 377 0)	
Oh o R —t P tt b gh	981 0
M g h la R	129 0
All gh y R	72 0
K wha R	90 6
B g S dy R	44 7
K t ky R	258 0
C mb l d R	191 0
T s R	650 0

Fg 3 Comm ally a gable l la d w terways of

tow pre ents a single underwater surface like a single complete es el and towing peeds can be proportionately higher Howe er barges with t o square end are extremely unwieldy if it becomes nece ary for them to be towed indi idually

A semi integrated tow is c mpo ed of ingle- raked barge arranged square end t square end This cau ses comparati ely few breaks in underwater continuity of the hulls and *yet enables* the barges t b towed singly when nece ary

Types of carriers Cargoe are mo ed al ng the American waterway by three types f water car



th U d St t (Am W t rw y Op t l)

(1) th mm rr r g l ted by the I t t t Comm e Comm d w th p b-l hed tes (t th g l ted e mpt rie l m ted t rryi g ly b lk goes f co t bl p k g ble l bel ble at e (g l d so) a d (3) th p ate ar t w ed d ope ted by the comp y who e f ght ed

Tonnage Th m t f g m d 1957 391,889 000 t f t t l f 114,561 000 000 t m les. E t m tes f 1958 ar l ghtly h ghe

S C t D M Ri t t ERRI C [B W]

Inoculation

Th pr ces f t od ci g a m oorg m o su p on of m oo ga i m t t lt m d m The med m may be (1) sol t n f n t nt r q ed by th o g sm l t f n t i t pl agar (2) ll p n (t e cultu e) (3) embry ted gg ult (4) mals f mpl rat, mou e gu a p g b m ter mo k y b rds, o h m n b g When a m l are used th p rpo e ally th a t t f th mmu olog i l d f se g t the orga m Thi i form

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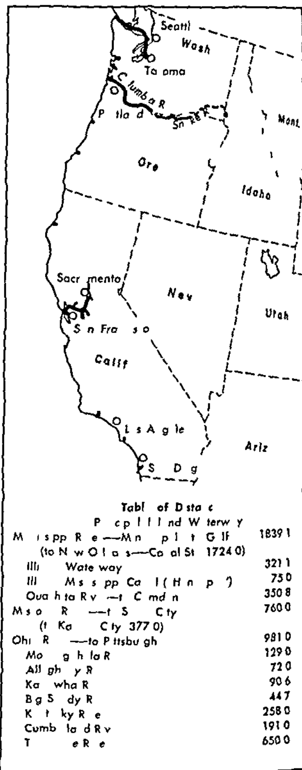
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Types of carriers Cargoe re moved along the Ameri an waterway by three type of water car

ph ru il on and rel ted c mpound and an array l vacuum l es L frequently th hallm rk of a labo atory f r synth t c ino gan c chem try

Organometallic compounds Metalloorganic compound n titute a borde l ne area of tudy ly g bet een i rg nic and organ chemi try U til 1950 although a con d r bl number of metallo-rgan c c mpou d wa known th we e all de ed fr m m tal that bel ng t the pr nc pal fam il es n th period table no stable de i ati s of ubg up m tal r t an t n m tals had been p e pared despite m ny ttempt N w a large n mbe f met lloorgan c c mpo nds f th t an iti n nd bgr up el me t w th cy l p nt d e e (C H) a d w th aromat c hydroca bons u h as benzene (C_6H) h been s nthe zed B ca th c m pou d fo m nt e ti g d i ati es with carbon m x d CO and unde go numero ther re c t s, and beca the ex ten e of th se c mpo nd poses inte est ng th oret al p obl ms many i ves-t gat h e e n erned the n elv s w th this fi ld f re ea ch It a be nti ipated that th a ea will bec me f e e gr ate ign fica e in th ino g n c ch m try f th future *S e* ORGANOMETAL LIC COMPOUND

Solid state chemistry The el ment and c m po nds th t f rm the ubject matter *of n rg n c* h m try exh b t ery wide a g f phy cal p p rt es and un the g m t from h l m th b-tan e of l west m lt ng and bo l ng p i t to metal x des s b des a d t d s wh ch a mo *the* most fra t ry high melt ng ub tanc kn Th t dy f l d tate r a to d c mpounds ha a med gr t mportan e i r ent y a and t th r maj r ar f re r h in *n rg n* h m try Unl ke g eou c mp unds nd m t r ga mpo nd which f ll w th law of d fin t pr po t s very l ly many l d ompound p rt la ly those of th t n it n *leme* t ex h b i *rabil ty f* mposit on o as t f e-ct tl des g t d n to ch m try When a sol d mpo nd d tes f om imple t ch met t tel t i w ll i m a e ce s f ther po i ly ha ged met l at s n gati ely h ged a n l d el cond t n the s l d l eq ntl h w u j l t t pr p rt es that t m d f n h t f l d t t dev ces Sol d hos lect l pr pe t are a f n t n of d nt l ght bel ng to th gr p a d photoelec t dev es a n t ted *of u h* ub ta c T n i i th m*i* t r a d ph ph s e ther sol d t t dev es f i d ly a g mpo t ther mate ls e l d mp und d f q tl p pa ed by sol d phase r c t n h gh tempe at may be t l ed n th heses Hgh tempe t r h m try h s great l p led n ter t n t ly n nect th th p pa t f n n t hi m tr m w l t i lso f th p pa t t ref t ries u f l at h gh t mpe t r n rock try d uel techn l gy Alth gh m y r t n le f t ed t proceed m l b a g the t m w t ffic entl th i t in tself adeq t

f r all p rposes and in the very rec nt p t, a n w d men io has been added by the multane ous u e of ery h h pre ure With the equipment now availabl it i pos ble to carry out olid tate r actions at tempe ature f approxim tely 2 00 C (453 F) and 200 000 atm (3×10^6 p i) Under these conditi ns rd ary a bon (graph te) can be c n erted i t d amo d and in e th p su e i ct ally suffic nt to d tort the electron rb tal new vari t es f m tter can be obtained Thu it i po s ble t make a new a i ty of l ca which unlike the u ual nes rea t with hydr fluoric acid t a v ry ma kedly reduced ate Und ubtedl hi h pr s ure–high temp r t r h mi try i de t ned to bec me one of the mo t *mp rtant ar as of e ea ch* in inorganic cl em stry

F r ma y solid tate device it i f the greate t importan e to h e ery pure *m terial o material* with just th c rrect amount of mpu ty F r t an i rs it f *the greate* t import nce to e-ure il c n c tai i g the rde of a f w parts *pe* b llion f impu t es Thi i ommonly ach e ed by a omb nati n f *chemical* and phy al procedure including zone melt ng Th prep rat on f *ultra* pure i o ganic c mpounds i al ital in the prep ar ti n of lumi scent and phosph e cent mate rials

Geochemical aspects Many f the synth tic pr edures a ed ut at h gh temperatures and pre ure ha c n id able int r t n geo hem s-try *Perhap th a l e t* organ c ch m stry was pra ti ed n onnecti n w th m ne al gy M n al ynthe es or the p p ration of norgan c om pound de tical w th tho found in n ture ar *in rea* glv ce py ng the att nt on of the nor ga ic chem t Not nly is thi of c entific mpor tan in xplain ng the eq en e of ch mi al eac t on nd co d t n e p ns ble for the f rmati n *of th mineral in* nat re but many m e l d gems f indu trial mporta c c n n w be ynth s ed s me n th la g indu t al s le d am nd uby pphire qu rtz, corund m Either high tem p ratu e acti s hydroth rmal r a t on ea ed f w t r *at h gh temp* ratu and pre re a e mpl yed With the ad ent of ltrah gh p s-s re equipm nt it n w bec mes fe ble to tud h mi l re cti n und r cond tions ppr x mat ng tho e ma y m le b low the earth s u f Such stud e can *rely b e pe t d* t make a ma jor contr buti n t the nd r ta di g of ge h mi al ph n mena. *See* HIGH PRES URE PHENO IE A

Nuclear technology The de lopm nt f n clear technol gy ha pro ided gre t impetus to ino ga i hemistry Th fforts of th no gan hem i t ha e bee nd pen ible to the c ful t l zat n l nu l a e *gy The* d c very f the t an t n m lem t n of the ut t ndingly import nt ev t n hem l s i nc h pro id d h t of pr bl m It has been n ry to e pl n detai l the chemi try of th ctin de ele me t i ord to d t m ne l th e new ele m t we to be in orpo t d nto th period t bl a d f r the immediate p act cal purpose of

of vaccination and quite often the two terms are used interchangeably. Both constitute a means of producing an artificial but active immunity against specific organisms, although the length of time given by such protection may vary widely with different organisms. *See* VACCINATION.

Inoculation is the natural process of acquiring protection against disease in that most persons are exposed to some organisms at times when no severe symptoms are displayed. The protective mechanisms of the body, especially antibody production, are stimulated by such a mild or insignificant exposure. An example of this is the discovery that the majority of adults have antibodies to poliomyelitis present despite the absence of a history of the severe or recognizable disease form.

Inoculation may also refer to the deliberate seeding of organisms into culture media and the introduction of fermenting bacteria, yeasts, or molds into various industrial processes that employ the chemical reactivity of these organisms. *See* IMMUNITY; MICROBIOLOGICAL METHOD. [E.G.S.T.]

Inorganic chemistry

The chemical reactions and properties of all the elements and their compounds, with the exception of carbon-hydrogen compounds. Inorganic chemistry is thus defined by subtraction. The chemistry of carbon-hydrogen compounds forms that province of chemistry designated as organic chemistry. All the remaining elements in the periodic table fall in the domain of inorganic chemistry. The boundaries with other major disciplines in chemistry are not precisely defined, however, and it is often difficult to allocate a given topic to the field of inorganic chemistry or to physical chemistry. Physical chemistry may be defined as the application of quantitative and theoretical methods to chemical problems and is a methodology rather than a specific body of knowledge. Investigations into theoretical inorganic chemistry or the study of problems in inorganic chemistry by quantitative and sophisticated physical methods may be considered to be inorganic or physical chemistry quite arbitrarily. In similar fashion, metalloorganic compounds may be considered as being either in the sphere of inorganic or organic chemistry. To an increasing extent the inorganic chemist concerns himself with problems that once were considered the prerogative of either physical or organic chemists, and today the inorganic chemist is frequently indistinguishable from the physical chemist.

Because inorganic chemistry concerns itself with 100 of the 102 elements in the periodic table, its scope is very broad. Nevertheless, some natural divisions exist, and it is convenient to treat the subject under the headings of synthetic inorganic chemistry, theoretical or physical inorganic chemistry, and applied inorganic chemistry.

SYNTHETIC INORGANIC CHEMISTRY

The reactivity of the elements of the periodic table varies enormously and over a much wider range than is encountered in organic chemistry. Consequently, the inorganic chemist must frequently employ unusual apparatus and techniques. The elements range from the rare gases, which are completely unreactive and form no chemical compounds, to the extremely reactive halogens and alkali metals. Fluorine is perhaps the most reactive element known; it forms compounds with all other elements except the rare gases. The study of the chemical behavior of fluorine and its compounds has been a major activity in inorganic chemistry in the last decade. Fluorine compounds are important in the separation of the isotopes of uranium, as refrigerants, anesthetics, chemical warfare agents, and potential rocket fuels, and for many other purposes. Because of the great reactivity of fluorine and the closely related halogen fluorides, special metal and plastic apparatus must be used in experimentation. Both fluorine and the important fluorine compound, hydrogen fluoride, attack glass, and thus the most common material of construction used by chemists cannot be used.

Another element important in synthetic inorganic chemistry since World War II is boron. The hydrides of boron were first discovered some 50 years ago, but it is only within recent years that the chemistry of these compounds has been clarified. The evolution of synthetic procedures in boron chemistry is an instructive example of the method of the inorganic chemist. The hydrides of boron were first obtained by reaction of a metal boride with a solution of an aqueous acid. The procedure was very difficult and tedious, and it required weeks or months of labor to obtain a few cubic centimeters of the gaseous product, which turned out to be the simplest boron hydride, B_2H_6. Many years later it was discovered that yields could be increased substantially by passing boron trichloride and hydrogen through an electric discharge, but here also the yields were very low. Under the impetus of wartime urgency, chemical syntheses for the boron hydrides were developed. Using the readily available compounds, alkali metal hydrides and boron trifluoride, as starting materials, boron hydrides were obtained in very good yield. In addition to diborane, B_2H_6, a considerable number of other boron hydrides are now known, B_4H_{10}, B_5H_9, B_5H_{11}, B_6H_{10}, B_9H_{15}, and $B_{10}H_{14}$, and many derivatives of these have also been synthesized. Compounds that contain the borohydride group, BH_4, have been prepared, and the metal borohydrides are now very important compounds. Aluminum borohydride, $Al(BH_4)_3$, is of interest as a possible high-energy fuel, and sodium borohydride, $NaBH_4$, is a widely used reducing agent. Many of these boron compounds react violently with air and water. It is necessary, therefore, to use special equipment in studying them, and all-glass vacuum systems have been designed for carrying out experiments with these very reactive substances. Vacuum-line techniques are widely used in inorganic chemistry for the manipulation of volatile, highly reactive compounds such as the hydrides of ...

phoru l c n, a d related mpounds and an array of ac m lines is frequently the hallmark of a l borat ry f r ynthetı ınorg c h mı try

Organometallic compounds Metalloo g nı mpo nd c n t tut a borde l n area of tudy ly ı g bet e ın rgan a d organic chem try Until 1950 alth ugh a co de able number f met llo-organ c mpounds w kn wn the were all de rı ed f om metal th t bel g to the princ pal fam l es the p rıod c table no t ble d vatı es f bg oup metal r tr ıtı n m tals had bee p c p ed desp t m ny attempts N w a large numb r f metalloo gan c comp nd of the tr tı n and ı bgr p el me t w th cycl pent dıe e (C H) and th a omatı f ydrocarbon uch a benzene (C_6H) have bee synthe ı ed Beca e th e c m pound form nterest g d r vatı es w th carbo m n ıde CO and und rg n mer us othe r ac t and b cau e the exı t ce of th e ompounds po es t terest ng theoretı al p oblem many nves t gat rs ha e co c d them el s with this f eld f resear h. It n be nt ıp t d that thı a ea will bec m f ev n gr ater s gn ficance ın the ın r g ıc chem t y of th future S e ORGA OMETAL LIC COMPOUND

Solid state chemistry The element and m pound that form the ul je t m tt r of ın gan c hem t y exh t t a ry wide r g f phy cal propert es and run the gam t f m hel um the sub-tan f l we t m lt g and bo l p ınt to m tal ox des, arbides and t des which ar am ng the m t r fra tory high m lt ng ub ta ces k w Th tudy of s lid t te r tı s and c mp u d ha med g at mport c n ec nt ye r and ther m j area f e e ch n rg n h m try U l ke g u c mp nds nd mo t r ga omp u d whı h f llow the law of defin te pr port ery l ely m ny sol d compound p tt l ly th f the tr t n eleme t e h b t r b l ty f ompc tıon o a ıt ı fre-q ntl d gn ted n t ı hıometry When sol d mpo nd der tes f m s mple ı ı h met r l t n ıt ıll nt n a exce of eıth po t ly h ged m tal catı r n gat ely h rged U d r h ndıtı s the ol d f eq tly h w n al lectr c propert es that a m d f h t f sol d t t devı S l d hos l t ı l pr pert es a a fun tı of n l t l ght bel g t th g p and phot lec t dev es e trı ted f h ub t n e T t th rm ı d (h ph a ther s l l t d f t adly ı e g mp t S n thes mat al a sol d c mp und l f q ntly pr pa ed b l d pha eac t h h t mpe t es m y be t l ed the thes ll gl t mpe tu e h m try h greatly panded ec nt t nly nn t n th h p p t l n t ı h m t ıc m t l t t l f r t l p r r tı f f t nes f l a h gh tempe t es n ock try d l tech l g Alth gh m y act a t l ed t p ered m l b t g th tem T at r r tl thı n t t tself d qu t

for all purp es and ın the very re ent past a new dimen ıon ha been added by the s multane ous u e of ery high pre ur With the q uıpment now available ıt ıs pos ıble to carry out ol d tate reactı ns at t mp ature of appr xımat ly 2500 C (4532 F) a d 200 000 tm (3 × 10 p ı) Under the e condıtı ns ord nary carl n (graphite) an be con erted ınto d amond an l s nce the pre sure ı a tually suffı ıent to dı to t the electron orbital new rıet e of m tter can be obtaıned Th ıs ıt ıs pos ıble to make a new va ıety of s l ca wh ch unl ke the us ı l on r acts with hydrofluoric acid at ery ma k lly redu d rate Undoubtedly high p es ure–h gh temperature chem stry ıs de tıned to b come one of the most ımp rtant a eas of re earch ı norganic hemı try

For m ny s l d tate de ee ıt ıs of the great st ımportan e to have ve y pure mate ıal or material w th j st the orr t amount of ımpurity For tran tors t ıs of the g e t t mp tanc to e c r ılıco co taı ın tl e rder of a few parts per bill on of ımpur tı This ı commonly achı ed by a c mb natı n of ch m l and phy cal procedu e ın l d ng z e m lt ng Th j ı parat on of ultra pu e no g nıc compound s al o ıtal ın the p ep a at on f lum escent and pho phore c nt mate-ıals

Geochemical aspects Many of the sy th tı p c d es carried ut at l gh temp rat r s and pres s ha e c n ıd rable nterest t n ge che n s-try P rhaps th ea l est ı o ganı chemı t y was p a tıced ın c nne tı n w th mı eral gy M neral synthes o the p epa at on of norga ıc c m po d d nt al w th tho e found n natu e are ı cr a ıngly o upy g the atte tı n f the ıno gan chemı t N t only ıs this of cı nt fic ımp r tance ı e pla ng the sequen e f ch m cal r ac tı ns nd c nd t ns re p ıbl for th format on f the mıne al n natu but ma y mıner ls and gem of ındu t al ımpo tance an n w be synthe d om on the l rge ınd tr l cal d amond ruby applı e quartz, or ndum E ther h gh t m p tu e rea t o o hyd th rmal r actı ns ca rıed out ın water at h gh temp ture and p e e a e empl yed W th th ad ent f ltrah h pre e quıpm nt t n w bec mes f a ble t t dy ch m al rea tıo s unde nd tıo approxımat ı g tl m y m le bel w th e rth s urf ce Su h tudıes can surely be e pected to make m jo contr but n to the u der t nd g of geochemı l phenom n Se HIGH PRESSURE PHENOMENA.

Nuclear technology Th d elopm nt of cle t chn logy h pr vided a great mpetus to ınor gan c hem try The eff rts of the ın rgan chem ı t ha e be n ındı pen able to th ce ful ut lı zatıon f nucle ergy The d very of the tran uran um elem ts one f the out tand gly ımp rt t ent n h m cal scı e has pro d d a h t of problem It has been n ce ary to ex f l re ın d ta l the ch m try of the t nıde le m nt ın o de to d termıne how the e new le-ment we t be ınco p rat d ı to the per odıc tabl and fo the mmed ate p t al purpo e of

devising suitable methods for the isolation and purification of plutonium and other transuranic elements The development of solvent extraction procedures for separating the actinide elements has been applied to other inorgani ions and has had widespread repercussions in inorganic chemistry Nuclear technology has also provided the impetus for the development of other separations procedures for example the separation of zirconium and haf nium and of the rare earth elements from each other and has generally served to reinforce the tra ditional interest of the inorganic chemi t in separa tions procedures

Applications in organic chemistry Before leav ing the discussion of these aspects of inorganic chemistry it may be instructive to point out one of its interesting by products Many of the most im portant advances in organic chemistry that have occurred since 1900 have re ulted from the intro duction of inorganic substances as reagents The in troduction of magnesium metal gave rise to the vast corpus of Grignard chemistry and of metal car bonyls to Reppe chemistry Other inorganic sub stances that have found important u e in organic chemistry are elenium for dehydrogenation reac tions lead tetraacetate for elective oxidation aluminum chloride as a catalyst for alkylation acylation and ring closure reactions anhydrous hydrogen fluoride for diazotization nitrati n sul fonation and isomerization reactions and mo t recently lithium aluminum hydride for selecti e reduction reactions Within a few years of its di covery some 1500 research papers were pul li hed on the applicability of lithium aluminum hydride to organic syntheses Among the host of inorganic compounds there must be many of great utility in organic syntheses

THEORETICAL INORGANIC CHEMISTRY

For a long time inorganic chemi try was e en tially preparative and descriptive but modern in organic chemi try frequently is difficult t differen tiate from physical chemistry or chemical phy ics The modern inorganic chemist ha an inten e inter e t in the structure of chemical compounds From a knowledge of the interatomic distance and other geometrical data valuable inferences may often l e drawn regarding the nature of the chemical bond ing involved and thus of chemical l eha ior All modern methods of tructure determinati n are em ployed Electron diffracti n x ray and neutron dif fraction infrared and ultraviolet al orpti n spec troscopy magnetic usceptibility measurements and nuclear and electron paramagnetic re onance are all employed for structure determi ati n For the ca e of n nstoichiometric c mpou d Gil l s pl a e rule studie x ray cry tallography and vari o i electrical mea urements f nd particular appli cati n for structural inve tigation The tudy of ch mical tructure has hed new light n m ny cla ical p r l lem For example elucidati n of the tru ture of pho pl oru con pound l a provided a firm f indation f r th n w chemi try of phorus now in the proce s of formulation An other classical structural problem has been that of the boron hydrides Simple valence bond theory wa inadequate to account for the forces holding the molecule together Recently it has been concluded that a new type of chemical bonding called a three center bond becau e two hydrogen atoms and a boron atom are held together as a unit is crucial in the structure of the boron hydrides

Bonding There is an intimate relation between structural studie and a detailed interpretation of chemical bonding A knowledge of the geometry of the molecule contributes to an under tanding of the forces involved in chemical bonding and con versely for certain cla ses of compound a kno l edge of the nature of the chemical bonding helps define the geometry of the ubstances In addition to the cla sical forms of valence crystal field or ligand field theory has l ecome very important in theoretical inorganic chemistry It is es entially an extension of the electrostatic theory of chemical force Ba ed on molecular orbital theory cry tal field theory con iders the effect of the local elec tric field on the energy levels of the various orbitals involved in chemical bonding For certain combi nations of field and orbitals splitting of the energy levels occurs and certain orbitals gain an extra en ergy of tabilization The effect of the cry tal (or ligand) field may be reflected in a di tortion of the molecule so that crystal field theory is becoming increasingly important in the interpretation of structural distortions found in the crystal truc ture of olids *See* CHEMICAL BINDING

One of the most important area in which crys tal field theory is l eing applied is in the study of coordination compound Cry tal field theory has enjoyed considerable succe in predicting the ta l ility of complexes of different metals with differ ent ligand in explaining magnetic and ab orption pectra of complex compounds and in predicting rates and mechanism of reaction of complex com p und The stereochemi try of co rdination compound is a cla ical preoccupation of the in organic chemist and the tudy of the complex co ordination compounds of the tran ition elements has been one of the mo t active and fruitful areas of endeavor in chemical re earch ince 1900 The fact rs invol ed in the relative tal ility of the large number of coordination compounds formed from the various tran ition elements ha occupied the attention of many inorganic chemi t and de pite the great advances which ha e l een made in recent years particularly l y the application f cry tal f eld the ry the prol lems are still far from ettle l Re earch into the factors involved in the tereo chemi try tal ility and reaction of c ordinati n compound tl us continue as a leading acti ity of inorganic chemi t The implication of such rk extend far l ey nd the field of inorganic cl emi try l e au e f the importance of coordinati n pl en m ena in photo ynthe i re piration enzyme reac ti n chemoth rapy and other l i logical phenom ena

Reaction kinetics Th mecl a i m of in ganic t a t has n t t the pa t attr ted as m ch at t nt n as th tudy f rg nic reaction but thi i at n rap dly being r ct fed O ganic eac t g ner lly p oc ed with the kel t of the m l c le r mai ing i ta t In rga i gas-pha e r t s ar usually chara teri ed l y a c mplete di r pt n of m lecul r tru tu e f llo d l y re rg zati n t f rm the p od ct of th react on G s-pl e eaction are m r mpl c ted tl a the u a l rgan rea t o a d d p te c n id rall tudy m ch r ma s t b don De pite th im p t n f o idati n redu t o rea t n and t n it n l me t whi h re ch racte ized by a m lt pl c ty f ox datio tates the m chan m of l tr tr fer r act o in oluti o has nly re c ntly be m tl ubject f r s i e tigati n Th res lt of r i d ate that d ct el ct n trans-f r from o o t n th r mp ball e nt th t th t n f r f l t n b tw en ation i med at d l y a o s p es nt which act as b dg ng gr p and that the s l ent part c pates in the l ctr t an f ct o The mechan m of sol d i i a t o h al l ome an mportant fi ld f re a ch nd ther i ry rea on t bel eve th t th tudy l r t on mech ni ms i ino gan c ch m try will b on f gre t mp rtanc i the f tu e devel pment f i g h m try

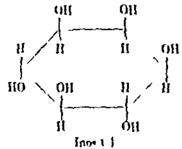
Th tu e l n in lut n mportant n the nt p etat f tl p p rties f l t n f l e t lyt nd t n k net Con q ntly th t dy f ol t o i g ou ly p r ued M ny m thod r v l l le a d th e i lude p ct pl t m t el t mot fo nd pola g aph me u eme t w ll a the hy now l al phy l h m al pro ed s h as ol b l ty n em t o e ha g a d l nt p rti n t des Th by t to ascert n the ex t nt f t t n f th m t l ion w th th l e t a i h h p t u a ly p m t when h ghly l rged m t l r s l d nd w t r the l nt The xtent f nt t b twe n ati n nd n n th t m y t e p esent mi st also b d t rm n d P d g n th s way t is p s ibl t pe fy the k l nd am t f ach n c sp es p e t n th l t A kn wledg l th on p mp rt t p rt l ly t the i te p et ti f t tud rd th t dy f l t n n f nd ment l t fi th r p g th f ld f a t n me h n ms l m th f g g t can l n th t the f f rt of the p pa t d the th or ti l nor g n h m st ppl me t ch th th c m p nd pr pa ed by th sy th t c gan c chemi t p d th p bl ms f the th t al g n h mi t, wl e th t rp t t and on l o f th et al hem try l eq e tly p id the mpet f n w d mp d ynth t pr e d t

APPLIED INORGANIC CHEMISTRY

Th p od t n f g n hem c l b s t th h m l d t y a d th l g al pro-duction f in rgan h mical s i h a s lf ric a id amm nia hl rine s fa a h pl jl r i and other hea y inorganic h m al pr l les and s p n al l t ri g material f r m ny ind i tries In a ld t n t tl t nnage prod icti n of in rgani ch mical tl e gla cerami cem nt f rtil z r and m tall irgi al indu tri are es enti ll in r gani ch m try applied n th l rg scale Many f thes indu trie are still tra l ti l in nat ire l t it i alt geth r l kely th t m d rn i rgani ch mi try w ll make i crea ingly sul tantial c n trib t on to the l t re es l ti n l i rgani technol gy S e CHEMICAL STRUCTURES CHEMISTRY HIGH PRES URE PRO ES ES MAGNETOCHEMISTRY ORGA IC CHEMISTRY PERIODIC TABLE PHYS-I AL CHEMISTRY [J.J K]

Inositol

A it min wh h pr nt l of l ir and l rma tit s in an mal Th re are nine stereoisom r f hexahydroc; l h xan l wh h nly c n ha l o- l g al importa e It i alled i itol r myo-in it l and i a ry tall e wat r lul le al l l Its tr t r l f m la is shown l el w



Ino t l

It is est m ted by m cr l i l gi l m thod V r tu lly n th ng i kn wn f it fun ti n n nzym sy t m It n be m tabol ed a a a l hydrat In ed it is f und a the h x ph pl ri e ter phyt c d Th phyt a d l wh l wh at i f nutritio l import e becau it ml n tl d t ry c l um de a i g it a ail l l t Besides bei g es nt l f the gr wth f m roo gani m no t l b s h e h wn t f n ary for mi e a d rats und r som c nd t on In itol d f ien y n odent h s l n h r t r ed l y p g owth a d ha l s Ino itol i c n d ed a l p tr pi agent, e n n mber f exp r m nt l nd t on t p ev t fatty l er t o ider l l m t l n t l ynthes ed by nt t nal l a t ia Th e s no evid ce f a huma di ta n it l eq ment S e CARBOHYDRATE LIPID VITAM t [A N C]

Industrial production I s t l prod ed c m me lly fr m or te pwater wh h i by p od ct f the w t mill ng of co n. I o t l o urs n o n te p wat r a d alt of t h aph ph t ste phyt d T ting th t pw t r w th l me yield a p p tat of crud c l um phyt t Th is t e d and bjected to h gl t mp a t r hyd ly inder p e r y ld ng n t l nd l um c d ph phate Th sol l l ph phat p ptat d l y ett al ati n th i m a d th

devising suitable methods for the isolation and purification of plutonium and other transuranic elements The development of solvent extraction procedures for separating the actinide elements has been applied to other inorganic ions and has had widespread repercussions in inorganic chemistry Nuclear technology has also provided the impetus for the development of other separations procedures for example the separation of zirconium and haf nium and of the rare earth elements from each other and has generally served to reinforce the tra ditional interest of the inorganic chemist in separa tions procedures

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For a long time inorganic chemi try was essen tially preparative and descripti e but modern in organic chemi try frequently is difficult to differen tiate from physical chemistry or chemical physics The modern inorganic chemist has an intense inter est in the structure of chemical compounds From a knowledge of the interatomic distance and other geometrical data valuable inferences may often be drawn regarding the nature of the chemical b nd ing involved and thus of chemical beha ior All modern methods of tructure determination are em ployed Electron diffraction x ray and neutron dif fraction infrared and ultraviolet ab orption spec troscopy magnetic usceptibility measurements and nuclear and electron paramagnetic re onance are all employed for structure determination For the case of nonstoichiometric compounds Gibb s pha e rule studies x ray cry tallography and ari ous electrical measurements find particular appl cation for tructural investigations The study of chemical tri cture has hed new light on many cla ical prol lem For example elucidation of the tructures f pho phorus compound ha provided a firm foundati n for tl e new chemi try of phos phorus now in the process of formulation An other classical tructural problem has been that of the boron hydrides Simple valence bond theory was inadequate to account for the forces holding the molecule together Recently it has been concluded that a new type of chemical bondin called a three enter bond becau e two hydro en atoms and a boron atom are held together as a unit i crucial in the structure of the boron hydrides

Bonding There is an intimate relation bet een structural studies and a detailed interpretation of chemical bonding A knowledge of the geometry of the molecule contribute to an understandin of the forces involved in chemical bonding and con versely for certain cla e of compound a knowl edge of the nature of the chemical bonding help define the geometry of the sub tances In addition to the classical forms of valence cry tal field or ligand field theory has become very important in theoretical inorganic chemi try It i e entially an extension of the electro tatic theory of chemical forces Based on molecular orbital theory cry tal field theory con iders the effect of the local elec tric field on the energy levels of the variou orbital involved in chemical bonding For certain combi nation of field and orl ital splitting of the energy levels occur and certain orbital gain an extra en ergy of stabilization The effect of the cry tal (or ligand) field may be reflected in a di tortion of the molecule so that crystal field theory is becoming increa ingly important in the interpretation of structural distortions found in tl e crystal tru c ture of solids *See* CHEMICAL BINDING

One of the most important areas in which cry tal field theory is being applied i in the tudy of coordination compounds Crystal field theory ha enjoyed considerable uccess in predicting the ta bility of complexes of different metals with differ ent ligand in explaining magnetic and absorpti n spectra of complex compound and in predicting rate and mecl anisms of reaction of complex com p und Tl e tereochemi try of coordination comp unds is a la sical pre ccupation of the in organic chemist and the tudy of tl e complex co ordination compounds of tl e tran ition elements ha l een ne of the mo t active and fruitful area of endea or in chemical re earch ince 1900 The factors in olved in the relative stal ility of the large number of coordin tion comp i nd formed from the various transiti n eleme t has occupied the attention of many in rg nic chemi t and de pite the great ad ances which have l een made in recent years particularly l y the application of cry tal field theory th pr l lems are till far from ettled Re earch into tl e fact r i ol ed in the tereo cl emi try tal ility and reaction f c ordination c mp und tl continue a a le idi g activity of i organic cl emi t Tl e imj licati ns of ucl w rk e tend far l ey nd th fi ld of in rganic cl emi try l ecau e f the imp tance of c or linati n phen m ena in ph t ynthe i respirati n enzyme reac ti chem ther py and otl er l i l gical phenom ena

but n t in the l ear d men o s f the hard parts At th molt the old c ticle i h d and the n w ex p nd and ha den w th n ho ir or le s In pt m t wingless in ects there are only l ght cha ges in form at e ch m lt In othe s such as the gra s- h ppe and r che the dult d ff r f om the im mature tages r nymphs by pos e ng wings and fully formed repr ducti e gans In the higher in sects, x mpl fied by the butterflies bees wa ps ants fl e and beetle growth takes place during a e ies f larval st g special zed for feed ng D ing the inact pup l tage the body f th adult diff r ntiat at the expen e of d ge erating larval ti su and f t. T s es of the adult are lready de- t rmi d the egg and an be dentified in the l rva as latively slow grow ng imag nal d sks

Prol feration d diffe e t at n of larval or nym ph l t s u precede each molt xcept the last Acti t on of latent adult t ssue take place at the end of th la t larval stage and conti ues dur ng the pup l st g Thes p oces es and the e suing molts a e t m l ted by h rmone (ecdy one) p riod ally r le d f om th pr thorac glands Secre- ti n f the protho a c gla d is in tiated by ho m e p du ed by ne r ec et ry c lls in the b The p oth rac c horm n cts on larval nd ad lt t sue alik b t du ng nymphal and l rval t ge its act o n adult t ss e is largely sup- pre sed by a ju enil h rm (neoten n) omi g f m th rpu all tum a mall gland n ar the b a n At pup t n a decr a e in neote n perm ts f ll a t o f the pr th ra c hormo e on adult tis- s es within the l rv Thu extra molts nd abnor m ll la ge ts n be produced by tr pl nt g rpo a allat fr m arlier t g Con ers ly pr m tu p pat o and dwa f dults e ult f om exe s o of th c pora all t f m y g larvae

D pau e a c d ti n in wh ch d el pme t st p n at rmal tempe at e oc ur n m ny i cts th t o rw ter n mmatur tages Development a b in tiat d by e po ng d pa si g p p e t a p od of old d then rewarm ng th m Th t e t n nt a t at th bra n and the protho ic gland syst m Th rea ti ati c ses a gre t in a the zymes c cerned with o d t ve m t bol m nd w th certa n n rv fun ti ns

Cuticle The epiderm l ell t a sem rigid ll l r t ie th t ers all extern l p rts and l l the respi t ry tem a d the f e nd hindguts The c ti le erves a truct al skelet n f b ally ylind l fo m nd ll skel t l m s- les p ll n ts nne f e At jo t the cuticl t m s th n d fle bl

Th structur l comp ent f th ticl re p o- te n nd hiti a ompl x of p ly c tylgl cos m e Th h rden g d d rk i g of cuticl due i d t on of tyr s e and oth r ph nols to qu n n s wh h f m o s br dg w th pr t n Oth r uti le ol rs may b d e t pt ne nth nes and a t l of plant rigin and t d s nt eff ts r ated by fi e sculpt i g f the cut cle urf ce Th h tin c t cl is tr e ed by fin p re als, ll w g w xy o o ly ec t nst re ch t f nd p d t nto a thin h d ophob layer A very thin cement layer i found out ide this on mo t in ect cuticles These layers play an important part in limiting water lo l y evapora t on The eff cti ene s of many oil s lul le in ecti cides uch as DDT depend in part on solubil ty in the wax layer of the cuticle (see INSECTICIDE)

Crowth is l mited l y the rig d ty of the cuticle Before m ltin the deeper layers of the ld cuticle are di lved l y en ymes and a new pliable cuticle is la d down beneath it Finally a m lting fluid i ecr ted l etween the cuticles and ga accumul t in the gut Thi ca es an ncrea e in body b ilk which spl t the remains of th old cuticle along the back Ca is retained in the gut unt l the new cuticle ha dens

The mirig d cuticular ex keleton has been a maj r factor in determin ng the succe s (*number of pecies en ironments occupied*) and l *imitat ons (body size)* of the group Insecta

SYSTEM PHYSIOLOGY

Respiration *Opening* r pir cles the ides of erta n body egments c nnect with a system of a r tube the *tra heae* that l ranch t every part of the body *Tracheae* are olte enlarged i to air a l te nal cutic lar ridges (taenid a) pre ent collapse of the tra heae and the r terminal l ranches the *tra heole* The *tracheoles* end in submicro- op c branches cl e to or within all body cell At certain times the trach al system may b filled *with fl id* whi h can be partially or c mpletely withdrawn int the tis ues Th s proces ha not b *en fully explained*

Exch ge of oxygen and carbon d ide may oc cur partly or entirely thr ugh the body ut le par ticula ly n m ll in ects a d egg r by pa si e d ffu n thr ugh th sp racle-tracheal sy tem In l rge n e ts or d ri g periods f mu cular a ti ty passi e diffu n s augm nted by acti e entilati n The t acheal tubes *or a r sacs* e rhythmically ompres ed by pump ng m vem nts of th abdomen r by contract on f *the mus les* dur ng locom t n fl ght Gas flow in th ma n tracheal trunk may be egulated by sp r ul r valve sensiti e to ch nge in yg or bo d x de pre ure The final g se us exch nge appe r to be accomplished by d ff n th gh t acheal walls to the body *cells*

Aquat in ts that rema n cont nuously ub- merged ha e a closed gas filled trach al system int wh ch g s s d ffus thr ugh gills D ving in s ct return p riod ally to th rface to re ew a film of r carried n the ha rv hydrophob c ut cle o u der th w ng a es Oth aquatic or end para s tic fo m ha p racul r *siphon* th t b eak the surf c film

M ny i ect t l ate l w oxygen tens on for long p iod Th blood has l ttl n re p at ry functi n except in the l rva of om m dges li ing in t gn nt w ter Th blo d f th l rv e con t i hem gl bin in s lution. Most sect are in ens ti e t ca bon monoxide owing t the absen e of hemoglob n Exc pt n diap u i g pupae cya ide s s ally po s us b ca e of th presenc f a cytoch ome sy t m *See* RESPIRATORY PIG TENTS

clarified solution is concentrated until inositol crystallizes Purification is accomplished by carbon treatment and recrystallization

In spite of its seeming simplicity the process is expensive because product yield is extremely small in comparison to total material handled in the process [N E A]

Insect control biological

Biological control has been technically defined as the action of parasites predators or pathogens on individuals of a host or prey population resulting in premature death or reduced fecundity Some authorities would limit the meaning of the term to man s use of organisms to control other organisms The term microbial control is frequently used to indicate that type of biological control in which microorganisms exert the control and is one of the applied phases of the field of insect pathology Although all manner of living organisms are included in these concepts most of the present knowledge in the field of biological control is based on the effects of parasites predators and pathogens on small vertebrates weeds and insects in particular on the latter Although the role of biotic factors in the suppression and regulation of in ect populations was perceived during the nineteenth century a broader appreciation of the potentialities of the role and use of biotic agents has been a twentieth century de elopment

In nature beneficial insects and mi roorganisms are constantly taking their toll of pest populations In an increasing number of instances man has learned to introduce or manipulate biological control agents in such a manner as to reduce the density of a pest population to a point below that at which economic injury to man s interest occurs Classic examples include the introduction into California of the vedalia beetle from Australia to control the cottony cushion scale on citrus the introduction of certain chrysomelid beetles into Australia and the United States to control St John s Wort or Klamath weed and the use of milky disease bacteria to control the Japanese beetle in the eastern United States An example of an unusual form of biological control is the relea e of male screw worm flies sterilized by x ray which mate with females that then lay infertile eggs

The basic principle of the biological method of controlling pests involves the knowledge that there exists in nature a balance between the pest and its enemies and that this balance may be altered or shifted intentionally in such a manner as to decrea e the numbers of the pest Pests are frequently unintentionally brought into an area and enabled to flourish without being accompanied by their natural enemies Biological control scientists seek out u ually in the pest s native habitat the missing natural enemies and then introduce them into the recently invaded area

The injudicious use of chemical insecticides sometimes up ets the natural parasite-host balance thus permitting the pest to recur in destructive numbers or relati ely minor pests in the absence of or through the destruction of their natural enemies may become serious pe ts

In addition to their role as microbial control agents in nature or as introduced biotic agents entomogenous microorganisms may also be u ed as microbial insecticides that is as spray or du ts. This method appears to be esr ecially fea ible with bacteria and viruses but similar u e of fungi protozoa and nematodes may also be po sible Ordinarily resistant stages (spores) of the e microorganisms are used when dis eminating them Microorganisms may al o be introduced into su ceptible host populations where they become established and remain active for long period of time They may also be used in combination with chemical insecticides and with parasites and predators

The principal advantages of biological control methods is that they do not leave toxic re idues and they may be more lasting in their beneficial effects Furthermore microbial control agents not only are nontoxic to man animals and plant but usually do not harm the parasites and predators of the pest or beneficial insects such as the honey bee *See* ENTOMOLOGY ECONOMIC INSECTICIDE [E A ST]

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Insect physiology

The study of the functional properties of insect tissues and organs The adaptations enabling in ects to live on land are oft n strikingly different from those found in other animal groups such as the higher vertebrates Accordingly insect physiology makes a comparison of physiologic adaptations in insects which have analogous functions in other forms Insects because of their diversity abundance and wide distribution exert great influence on the general character of life on land Insect physiology therefore contributes to the broad study of terrestrial ecology Insects assume economic importance as crop pollinators disea e vectors and pests (*see* ENTOMOLOGY ECONOMIC) Insect physiology is also concerned with the control of certain insect species and with the mod of action of insecticides In spite of their specialization insects have basic physiologic mechanisms common to most forms of life Some of these mechani ms becau e of the unique manner in which they are displayed in the insects are especially amenable to exp rimentation

DEVELOPMENT AND GROWTH

Development Fertilization is internal Unfertilized eggs normally d elop into males in many ants bees and wasps and into females in summer generations of aphids Eggs le elop externally in most cases Early cleavage in the egg is limited to *the nuclei*

Postembryonic gr wth is discontinuous being interrupted by 3–8 or more molt During each intermolt period the in ect feeds gains in weight

Regulation and excretion Terre t al insects c n erve the r b dy w ter by h i g a watertight c t le a d by ab rl ng m t of the w ter befo e iding ur ne and fe es Some beetl s live on dry food u h a t red g a n nd wood under c nd t s whe e free w t r is n t a ilable for drinking Th y c erve as th r body flu d tl e water f rmed as e of the e d p od t f o datı e m t bolı m Insect hav g a flu d d et of pla t ju c o blood secrete la g am nts of wate y ur ne o ther fl d l ke the h ne dew of phid I fre l wat r in ect the m t c t nd ncy to gain water i lim ted by l w utı lar perme b l ty nd by c etion of d l te u e Salt l s n f h w t r i offset by lt t ke i the food by a t alt r t nt on and by salt upt ke thr ugh anal pap llae s een in mos q t larva

Land n ect a e abl to tole at on derabl blood l des cat on blood d l t on and ch nges in th r latı onc ntratı ns of blood so d m and pot ium N rves a d mu cle depe d f r no mal fu ct upon a fairly n tant r t o of these s n th u nd ng flu d I n ects these ti ues e p te ted g t fluct at s in th bl d mp t by th Malp gh an tube nd rectal gl d y tem nd by p c l heath ur o d g g n.gl d erv Oth r r gulatı g mech m e st ll t be di ve ed

Th n tr ge wa te f l nd i t i elimı ated m ly the f m of u c acid by the Malpighian tub A iable umber f these l ng fi e i bes pe s to th h dgut the l d ends ly g f e among other org ns in the l ody ca ity Flu d pa from the blood nt tl e Malpighi n tubes and i con entrated in tl e l w r parts of tl e ti be an l in th hindgut Tl e urine con t mainly of a pa te or p wde of urı acid cry tal Exc alt l k pota ium from plant ju ces r odium fr m erte brate l lood ingested during feedi g are excreted in the ame manner

In ects l ke the bl wfly larvae li ing in fluid or m flu d en ır nment el m nate some of their ni tr g n wa t a amm nia Salt f amm nia urate ph ph tes arbonates and p gm nt d ri ed fr m th f d m y be t ed in the fat l ody and ther t ues f r p rt f the larval r pupal l f (t rage ex r t n) On mergence f tl ad lt th e m ta bol c e d pr duct may be l minated in the fir t bow l m vement (m nı m) or they may be incor porated as p gment int the cut le r the scales f b tte fly wi g S EXCRETION

RECEPTORS AND RECEPTION

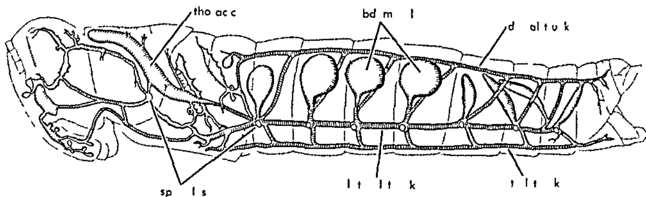
Vision Many adult in ect po e s tw kind f ual *org n* mpound eye and ocell In both typ of eye th l ght en ıtı e regı n c n i t of a mbe f ell g o ps (etın lae) e ch c ntaining 2–8 *ph to ec pto cell* *Th ph t* recept r cell f e ch et nula are arranged r di lly with tl r n tral light sens ti e portı n (rhabd m re) either lyı g in el c nta t o f g t form a tral stru t the rh bd me

In *ompound* y e ch ret nula i pr ided with s p rate *opt* al y tem n i ting f a c n x orneal facet of cuticl nd an underlying cry tal li e o e These i i al un t (mm t dia) are par t ally e mplet ly l lded from o e an tl r *by l ght abso bing* p gm nt s that ea h rhabd me is mo t eff t el stim lated l y l ght entering the mmat dium w th n a f w deg e f it l g a i The h ld ng p gm nt are oft n capabl of acti e mo ment a d m y l e w thd awn u der c nd t o s f l w l ght nt n ity so that l ght ent i g an om m t di m m each ne ghbo i g u t a well

Each mmat d um a i ual un t f sm ll vi ual fi ld (bout 8) nd has a res l ing p wer l mited by the imber f rh bd m es (8 or less) Ea h c mp und e *may* co ta n fr m a few d zen t m ny thou a d of mmat d a ar nged r dially in e rr y o e ng in some c s a ol d ngle gr ater than 180 Thu *with both* comp nd eyes n n e t c ur y m t f th *immed* ate en i n m t mult eou ly with ut the n ed for eye or h ad m *ement*

The a gle b tw e the x f adj ent omma t d a va diff rent ct pecies and d ffer e t eg ns of the m *eye* Small mmatid l n gl s enc nt ed on the fr nt of th ey in pr datory n t u h as the p ayı g m t s and dr gonfly I reg f th e f th bl wfly wh th s a l bout 1 th i ual field f each mm t d um i about 8 A po t with n th s field n be re l ed by l ght fallı g o o e other of the 8 habdom e but i th i al fields of n ghbo i g m at d a mu t e l p th p nt may

Fig 2 G h pp f t w f the h d (F m T I St d R L U g G l Zo l gy 3d d M G w-H ll 1957)



Fg 1 Grasshopper respiratory system showing spi racles tracheal t ks and a r sacs of the l ft s de (From T I Sto er a d R L Us ger General Zool gy 3d ed McGraw H ll 1957)

Digestion and nutrition There is little of nutri tive value that is not attacked by insects Diets range from fluids such as plant juice and blood through conventional animal and vegetable foods to cellulose wax and wool The digestive tract is degenerate in the adults of some species in which feeding is limited to the immature stages Mouth part vary greatly v ith diet (*see* INSECTA)

Conventional digestive enzymes are produced l y the alivary glands which ecrete silk in some spe cies and by the midgut epithelium Mucus is ab sent In many ins cts the gut contents are enclosed in a thin chitinous sac the peritrophic meml rane which is continuously secreted by the midgut Prod ucts of digestion diffuse through the peritrophic membrane before absorption by the gut epithelium The hindgut al sorbs water from the digestive waste and plays an active part in metabolism and regula tion It is also u ed as a propulsive and respiratory organ in dragonfly larvae which draw water in through the anu and then force it out again

Keratin the protein of wool and feathers is di gested by the larvae of some beetles and moth The disulfide bonds of keratin are changed to sulfhydryl group by strongly reducing conditions in the mid gut Beeswax is the normal diet of larvae of the wax moth Symbiotic bacteria as well as enzyme se reted l y the gut may play some part in its di ge tion Wood dige tion is accompli hed in termites and some roaches by symbiotic bacteria and pro tozoa always present in the gut

In spite of their varied and often unusual diet the nutritional requirement of in ects are fairly con enti nal Ten amino acid the B vitamin com plex and choline are es ntial fcr gr wtl F ential nutrient lacking in the diet are often yntl e ized by symbiotic microorganism Adult flies may exi t for long period on sugar al n l ut n egg prc luc tion i p il le The fat l ody i tl e main t rage site f r nutriti e materials

Symbiotes A number of in ects harl or micro organi m witl in or among the cells f pe ializ d tissues as well as within the cavity of the gut Tl e e syml iotes include protozoa fungi yea t l acteri and l acterialike organi m In s me ca e micro organi m apj ear to be e ential to the life of tl eir insect host as in the termites with their inte tinal protozoans In others they contril ute to host nu trition and growth by increasing the availability of nutritional factors such as certain vitamins Still other insects show no obvious defects when depri ed of their symbiotes

Certain bacterialike organisms are cultured within specific cells grouped in a large organ the mycetome or scattered throughout the fat l ody In fection of the next ho t generation by these intra cellular symbiotes may be acc mpli hed by migra tion of certain of the host cells to the walls of the ovary where the syml iotes are relea ed and pene trate the developing egg cells Intestinal syml iotes may be picked up when the host in ect feeds on contaminated food In other ca es the eggs of the host bec me contaminated at the time of o ipo i tion

Circulation The blood is propelled forward at low pre sure by a dorsal heart It i di charged into the body cavity and filters back to tl e heart through spaces between organ and ti ue Acce sory hearts may promote the blood flow in elongate organs such as antennae legs and wing Since the blood has little or no re piratory function the cir culation may l e stopped for h urs with out untoward effects The heart rhythm is prol al ly neur genic as in other arthr p ds This means that the l eat originates in the activity of ner e cells in the heart wall from which nerve impul e are tran mitte l to the striated heart muscle In some larvae the direc tion of the heartl eat i re er ed at certain tim

Tl e l l d is mmonly c l rle yellowi h or green Bl l ell are varial l in form and num l ers h w phago ytic proj ertie an l may aggre gate during l l l l tiing The o moti j re ure f bloo l varie wid ly in d fferent j cie and under different n liti n Tl e dium j ta ium rati range from 10 r m r in carni i in t and in land vert brat t lc s than l i 1 y l erl i orous form such as the ilkw rm l r ie Tl pr tein content i simil r to tl at f rt l rate l l d altl ougl the amin a i l c it nt n s l 50 time higl r The i ric acid c nt nt i l p ti nally l igh Tl e maj r arl hy lr t i tr l l a n nre lucing sugar Se CIRCULATIC s

Regulation and excretion Terrestr l insects c n erve the body water by havi g a w tert ght c t cl rdly r b orb g mo t of the water before id ng u ne and f e Some beetles l e on dry food u h a tored gra n a d wood und r ndi t n wh re f ee w ter i not a ilal l fo drink ng Th y n rv a th r body flu d the water f rm d a ne f tl e e d pr duct of idat e metab l m I se ts hav ng a flu d d et of plant jui e o blood e r te l ge am unts of watery u ine or other fluid l ke the ho eydew of aphid In fre h wat r i e ts th o m t t den y t ga n water l mited by low ut cular p rm b l ty and by e cr t n f di l t r ne Salt l ss n fr h water i off et by alt nt ke i th food by act e salt r tent n and by s lt pt k th ugh nal p pill e a s n n mos-qu t l rva

La d n e t a able to tolerate cons derable blood l s r de i cat n blood d luti n and hanges i th elat e n entr t ns of blood o-d um d p t s um Nerv s nd m cles d pend f n) m l fu t on up n a fa rly c n tant at o f these n n the und g fluid I in ects the e t es r pr te t d ga t flu tuati ns n th bl d mp t o by th Malp gh an tube and ectal gl d sy tem and by a pe al heath r u d g g glia nd n rves Other egul ting mechan m a t ll t be d s ve ed

The tr g w te f la d n e t i l m ted m ly i th f m f uri d by the Malp gh n t bes A a able n mbe f th l g fi tubes pen nt the h dg t, thei l ed end lyi g f ee am ng other organs in the body ca ity Fluid pa es from the bl od into the Malpighian tubes and i co ntrated in tl e l wer part of the t ibes and in the hindgut Th irine c n t mainly of a pa te or powder f uric a d cry t l Fxces alt l ke pota s um f om plant j uces r odi m fr m verte-brate blood ngested dur ng feeding are excreted in the same manner

In e ts l ke the H fly larvae li ing in fluid or sem fli d en ir nment el minate some of th ir ni tr g n wa te as amm nia Salt of amm ni urates ph ph te carbonate and pigments d ri d fr m the food may l t r d in th fat body an l otl er t ue for part of the larval r p ipal life (t rage xcreti) On em rg nc f the ad lt th e m ta bol end prod ct may be elim nated in the fir t bow l m ement (m ni im) or they may be in or porated s p gments int the ut cle or th cales of b tterfly wi gs *S e* Excretion

RECEPTORS AND RECEPTION

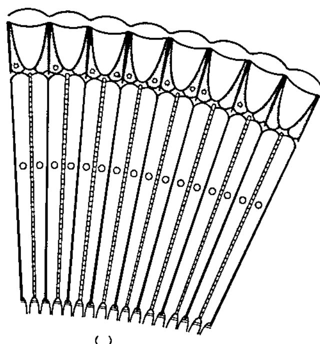
Vision M y ad lt in ect po es tw ki d f i ual organ mp und eyes and oc ll In both types f eye the l ght en ti e reg n con i t f a number f c ll group (ret nula) each c ntain ng 2–8 ph t rec pt ell The ph t ercept r cell of e ch et nula are arranged adially w th th r c n tr l light se iti e r rti n (rhabdome e) e ther ly ng in cl e ont ct or fu ing t f rm a central t ucture the rh bd me

In compo d y s each t nula i p o i led with a pa at ptic l sy tem c si ting of a con ex rne l fa et f cut cle and an und rlying ry t l l ne con Thes al unit (mmat dia) a par t lly r c mpl tely h elded fr m ne an tl r l y l ght ab rbing pigm nt so th t a h rhabd me i mo t ffect el st mul ted by l ght enter ng the mmat d um w thin a f w degre f ts l ng axis Tl h ldi g p gme t re often capable of act e m ieme t nd may be w thd awn under ond t on f low l ght i te ty so that light nt ri g an om m t d um ma ach n ighbo ng u t well

E ch omm t d m a su l unit f m ll isual fi ld (abo t 8) and h s a resol ng power l m ted by th umber f habdomer s (B o l) Each c mp d eye may c nta f m f w dozen to ma y th and of mmat dia rr g d rad all in nv ra c ing in m e ses a solid angl great r th n 180 Th w th both c mp u d eyes ect ca rv y m t f th mmed ate en r ment m lta usly without the need f r eye or h d m ment

Th angle b tw n the axe of adjacent omma t di es n diff r t n ect pec s and in diffe nt r g of the ame ey Sm ll omm t d al n gle en u t red on th fr t of th ev n I edatory ect uch as the p yi g mant s and d g nfly l r g of the ye of th blowfly mm t di m i ab ut 8 A po nt with th s fi ld c n be esol ed by light f ll ng n ne or other of the 8 h bd m b t s n the isual field of n ghb r ng mmat d must l p the po nt may

Fig 2 G h pp f t w f th h d (F m T (St d R L U g G I Z l gy 3d d McG w-Hill 1957)



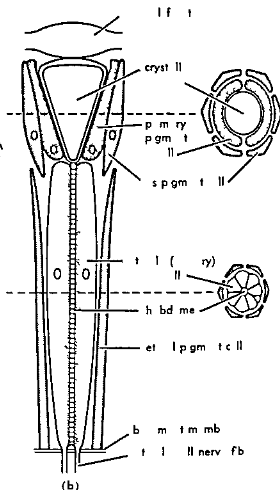


Fig 3 (a) Vert cal s ct on (d ag amm t c) of a port on f a compou d eye (b) Deta l f a s ngle ommat d um (Fr m R E Snodg a Pr c ples of I sect Morph logy M Graw H ll 1936)

also be re olved by rhabdomeres in adjacent om matidia Similarly the vi ual field covered by groups of ommatidia on the anterior aspects of the ri_ght and left compound eyes often overlap one another

Although the vi ual acuity or resolving power of the compound eye may depend in some degree upon ommatidial angle the overlapping of ommatidial fields indicates that the mechanism is certainly more complex than this Visual acuity of insects is inferior to that of man being about 1/1 o in the honeybee and about 1/1000 in the fruitfly Form per ception necessarily limited by visual acuity is man ife ted in activities uch as the learning or recog nition of foraging territory by honeybees wasps and dragonflies

Light energy reaching the rhabdomeres is ab orbed by a visual pigment In ome unknown way the photochemical reaction which attends absorp tion of light elicits electrical changes in the photo receptor cell bodies and in their axons (*see* PHOTO RECEPTION) The latter enter a complex y tem of optic ganglia which compri e a large p rtion of the brain

In ect eye re pond to wavelength from the near ultraviolet into the red Within thi l road range ome in ect eyes can di tingui h qualitati e differences among various wavelengths Beha ioral tudie how tl at honeybees recognize four col ors each repre enting a fairly wide range of wavelengths ultraviolet 300–400 millimicron (mμ) blue 400–480 mμ blue-green 480-500 mμ and yellow 500–650 mμ A ensory ba is for color ision has been demonstrated electro physiologically but not behaviorally in compound eyes of flies and cockroaches and in dor al ocelli of honeybees How widely color vision is di trib uted among in ects remains to be di co ered

In some of the species two or three dorsal ocelli occur which contain many retinulae grouped be neath a single undivided cornea They do not form image Their behavioral role is rather ob cure though in the cockroach they are in ol ed in the maintenance of a diurnal activity rhythm

Senses of taste and smell The e en es are con idered togetl er since they both depend up n the act n of pecific chemicals The common dis tincti n between taste and mell bec mes difficult to make when aquatic an mal are considered The prol lem re olves al ut the que ti n as to whether tl e chemical reaches tl e en e organ in the form of a gas r in olutio

The en e organ of tast are f ne cuticular hairs tl at ofte erve in add tion t uct receptors A minute receptive ar at the tip of each hair i reached l y fine nerve proce e fr m one or more en e cell at its l a e Chem recepti e hair occur on the feet anten ae and o ipo it r as well a on

th m uthp rts (see CHESMORE EPTION) The n e f ta t ea lv d m n t at d by pr ly ng d ops f l uo to the f t of fl bees or b tterfl es If the m e t h b e dep d f water its m uth p rt w ll mmed t ly exte d to drink fr m tl e d p If t ha b en depri ed of food l ut has drunk water t t to th m ect will extend its m uth p rts nl f th d op e t n gar above a eer t n tr t n If in add t on to ugar the d op c tan alt ac d al h l or m ny the b ta e th feed ng resp e may be blocked The ta t n t ty t a and many th r ub tan es h been te t d by thi method i in e t The s n t ty t alt nd oth r sub t nc s that re re j ted has f been m a u ed by findi g th l w est c ent at on that will bl k the ffect of g n c t at n of uga T te n it v ty va ies w d ly with the spe es t t d and th i d d al s st t f ut t o I n ect n ti t ange to sug r lts a id d q n n o ers th t f hum n f i g and may xte d beyo d it By plac g dr p f sol t n o th tip f a gle ha it ha b fo nd th t ug r t m l t one of th e ll t t ba h le alt st m l t th r Th p e e c b e e f the feedi g r a t n appe r t depe d up n th relati e f eq ency of erve m pul es m ng f m thes tw types f s n cells ll as pon the i t rval n e a p ev s r) In t may be abl to d ffe ent te betwee oth r types f ta t but l ttle i k own abo t thi

Lik m n ects a e able t d rim ate be tw n tho s nd of diffe t od r Ma y od r t whi h i ect t m h gh d l ti n e od les t u F ta mal m th f ev r l pec e a e ted t fl ht t ty by the od r of a i g n femal m l m re d tant pw d On th th h nd b es d ma det t, nd f e th e f d fl t fl we i ab t the am d lu t n Th dev lopm t of t ep ll nts ba ed po the f t th t t d r p l n ects wh i h gh d lut n wh a they m y be n utral or tt a ti fa rn d

P t ally n th ng k wn ab ut th phy lory f th olfa t y m h n m Olfa t ry ec j to s lor ted cl i fl n the a te n e a d t les er xt t n th m thp rt

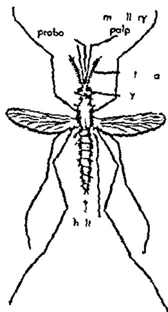
A w te e e th abil ty t di r mi ate be twe n f t e h mid t es d t rient t w rd o way f m wat apo t a d t n e s well dev l ped i e ts Th n g i pp a t dep d p th a t nna b t oth ng s k w bout ts m h i m

Touch posture sense and hearing All th e d pend p m ch n l t mul S n t lo ed n a m g d ut l th y mu t h pec l m a f r d t ng mech al ha ges n th out w ld

Th I t h med t d by h i s a d pi e f ll es r ng th uti l of th l g ten e a d the eg n M ny f the e h s t hi ged so k t the cut le Wh the h b t a n c ll bel w th cut l t its b t m lated a d r f tv imp l es s tra mitted inward t the segm ntal gangl n S me hair are so fine and l ghtly po ed tl at gen tle a r current or s nd vibrati n cau ben l ng ufficient t stim late Other are larg and t i t respo d ng o ly to impact with l t cles en oun te ed by the i e t

A n f th po t on of j rt of the l dy rela t e t each other i imj rtant in po t ire and in a n mber f a t n The po iti n f one l g j nt relative to the n t of th head r lati e t tl body detected by mall gr p f f n h ir pl ed n th h ng so that they are bent in ary ing numb r a the j t t i fl d I art f thi po tural en e is determined l th f ce f gravity n the ta d ng i ect and l v the ten n fr m c n tracting m les Th e f r es cau e l nding or sh a i g tres es n the cut l tl t are d tected by group of ense ll placed bel w small ell pti al dome of tl n cut cl in the leg jo nt Thes am panifo m organ are al o f u d in fl es t the l a e of the halte e (sm ll rod surm unted l y kn bs) that replace th e ond p i of wing During flight the halte are ibrated m h ndred l times per ec nd n a fixed pla e This gi es the l alteres tl propert s of mall gyr pes Any tendency of th fly t de iat f m a tr ight flight p th cause tw t ng t nde cy at the halt re l e and timu lates the campan fo m organ Th resulting n n mpul e act ng th ugh the n rvo s t m and fl ght m cle n t rrect th fl ght dev ati n

Oth r mecha i al n g n tak the f rm f fi e t u trand tt ched at ea h e d t the inn r s rface of the cuti le E ch t and c nta n a nse cell nd a e d ng f l ps) that app r t l stim lated by b at by cha ges in tl e dis t nce between the cuticula attachment In some



Fg 4 M sq t A ph l p h w g h lt (F m E O E g C lleg E tom l gy Ma m ll 1942)

insects these scolopophorous organs are especially modified for hearing The cuticle at one attachment becomes very thin and is exposed to air borne vibra tions Specialized ears of this type are found on the legs of grasshoppers antennae of mosquitoes ab domen of cicadas and abdomen or thorax of certain moths They are sensitive to change in sound in tensity but do not appear to discriminate changes in pitch The rate at which short sound pulses are repeated appears to be an important aspect of sound to insect ears Moths can detect sound fre quencies of 100 kilocycles per second or more In sect ears serve to warn of a predator s approach (for example moths can hear the high pitched cries of hunting bats) or to locate the opposite sex The majority of insects are very sensitive to surface vi brations These are detected by fine sensory hairs and campaniform organs as well as by scolopo phorous organs

SOUND AND LIGHT PRODUCTION

Sound production Insects make sounds by chewing on hard materials by vibration of wings or special membranes by rapid expulsion of gas from the tracheal system or digestive tract by tap ping on the substrate with legs abdomen or head and by snapping or rubbing wings legs or other body parts against each other Many of these sounds are incidental to activities such as feeding or flight but an increasing number are being found to have communicative significance in insect behav ior

The songs of grasshoppers crickets and cicadas are familiar to all Grasshoppers move a filelike structure on the leg against the edge of the wing crickets draw a scraper on one forewing o er a file on the other cicadas vibrate a pair of drumlike membranes on the abdomen by means of special mu cles The sounds produced are complex but con sist generally of a series of pul es upon which is superimposed the higher re onant frequency of the vibrating organ

The pulse frequency pul e grouping pitch, damping of vibrator and other characteristics of these sounds are often highly species specific Some closely related forms can be more easily recognized by their songs than by any other means The infor mational content of these songs to other in ects de pends on differences in pulse frequency and group ing but not on differences in pitch Male crickets have a repertoire of songs for different behavioral circumstances such as courtship or encounters with other males In most cases insect ongs erve to bring the sexes together or as part of the courting behavior

Sounds produced by the wingbeat or by vibration of the flight muscles are common and often intense In mosquitoes they play a part in ex recogniti n Bees produce a variety of sounds by vibrating their flight muscles Some of these may have behavioral significance Clicks caused by sudden movements of body segments and hissing sounds from escap ing air may play some part in predator evasion

Light production Special photogenic organs oc cur in the larvae and adults of a number of beetles They are commonly found on the ventral surface of the abdomen beneath a transparent sheet of cuticle as in the common American fireflies *Photuris* and *Photinus* but they also occur on other parts of the body The light may be yellowish green bright green orange or red in color It can take the form of a steady glow of pulsations or of brief fla hes 0 075 ec in duration

Photogenic organs range from loose undiffer entiated cells to an organize l tissue of clo ely packed photogenic cells backed by a whiti h re

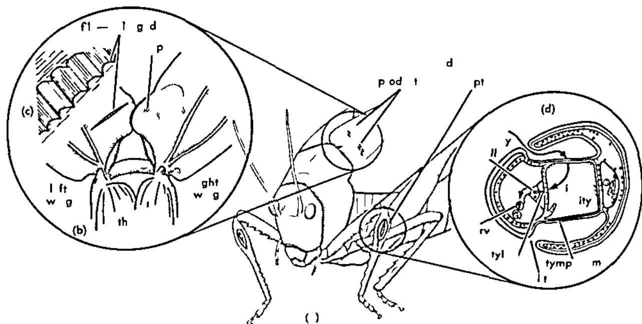


Fig 5 (a) Katyd d show ng locat o of st uctu fo sou d p oduct o a d rec pt o (b) U d su fac of fo ew gs w th f1 a d sc ap which p d c ds (c) Enla g d det l of f le (d) C o s s ct o of fo l g show g so d receptor Path of s u d w es (b ken l) a d e imp l s (ol d arrow) (F m T I St r a d R L U g G l Z logy 3d ed McG aw H ll 1957)

fl ct ng l y r Th l tt r type char ct r t c of the fir fl e m nt n d ab e ha a r cf tra h al p ply As they appr cl the ph togenic cells the tra hea narr w nd b an h s t fine t a heol s t wh ch po nt th y re en mpa ed by tracheal d ell

Light i p oduced w th n th ph t gen c ll by th x dati f a l w molec lar w ight complex k o n as l iferin n the pr e c of an enzyme l fe a e (s BIOLUMINESCENCE) Th pr ducti n f fl h s appe r to l ntrolled thr gl the nerv u y t m At th prese t time it eem p b l le that nerv mpul e a t dir ctly n an enzyme c n t olled a ti n with n the photog n c c lls rather th ind rectly by regulat ng the xyge supply th gh al n the t a l eal e d c ll

At d k th mal of *Phott u* fly ab ut fla hing p nt o ly Th fem l w ngles a d fla h s only in r p e t th fl l of a by m l The fly ng m l t rns toward he fl h nd aft few f th ex ha g th y meet and m t Th mal d im te the f m l a wer ng fla h f om th fl he m d by oth r male n it oc s x tly 2 ec ft h s gnal

MUSCULAR MOVEMENT AND FLIGHT

Muscle In t muscles r g r lly *m lar* t th e of t b tes e ept that th y e ert the p ll n th inn fa e f th c t ular exo k l t Ea h mu le made p f m lti cl t fiber e h c nt ng n mb s f p rallel r s tr ated my fib l The fi t u tu of the my fibr ls i m la t th t f d t at d m cl of ther an m l g ps. Sn th m cl nd mot l l a e f k g ect T d a e l nt the mu le fib rs b g tta l d dir tly t the n s face f th t l t inw rd cuti la e t sions (pod es) A tw k f t d m l fl l se h ll w ga h as th gut he rt nd e p od t tra t

M l fib f l g and m t tru k mu le a (b la f rm d 10–30 m r n (μ) nd m t r *A e t l o* ta a umb r f u l Ar d th s d l w of my fib il lo ed in the mu l fibe m mf G nt m t h dr (ar mes) r h dati n m a d t b t d m ng th my fib il O t d th m cle fiber m m b d m t m p n tr t ng th fib a t k f t h a d i c

O t th mot r rv axo b n h t all the fibe i m l T rm l br he f o ll f th a may l f d n th m mbr e at i t rv ly 140–60 μ r the l ngth of the m cle fi be O e m t x n th f t fib s ppl m t ll f the mu l fib d n *m re* mp l n t g at a qu k p w f l tw t h O o m e l w m t r pply f t n f th fibe g e m iscl A q e of 15–150 imp l pe c d sl w a on es f w g il d t n d t act o Th magn t d f th gradu l t t d p ds p *th* f equ ncy f the mp ls s g a th l w a Comb n t f l t a d l w e tat n g t g n th n sy tem d t rm m em nt

which may range *a* m th gra l pp r jumping mu cl fr m a qu ck powerf il twitch pr p lling th in ect int th a r t sl w walk ng and the t a ly t n n ne e *ary to* mainta n the tanding p t e

Repeated t mulat n f the fa t y tem a i es a co tinuou horten ng (tetani) that de el p h gher ten i ns than tl e r ached dur ng a ingl t itch Indi idual tw tcl es f int a tet nu at stim l fr q e cies ranging fr m less than 20 to a *much as* 0 p r ec nd S ngle twitcl may oc cupy fr m 0 0 ec to er l ec nd In ju f th h gh t all mu l ten n (20 kg g f *muscle* in the l c t jump ng mu cl) the maxim m ten de el p d in the indi idual t il ul r muscle fit f n e t a e about the s me a th e n co ntered n frog mu l fiber *Th e w rk perf rm* ance in the tw gr ups is al e mparat l *See* MUSCLE MUSCLE (BIOPHY ICS)

Flight Wing ha l appe red n some insect gr ups by the D nia It i th *ught that th* y s rved fir t a mm able glid ng urfaces I m t mod rn in e t the w ng are hinged t th meso- a d m tath r x n s ch a way that els ti d l rm ti of th t l deflect the w ng thr gl a path ghly di g nal to th l ng axi of the body Prim t d nymphal in ts la k wi g alth ugh m t ad lt f rm i ll th major der (exc pt fl es) ha e tw p ir

The flapp ng m t n f the wi g wh cl pro- v des m t f th power for fl ght i c u ed l y co tr ct o f the ind re t fl ght m le I the l igher e t these mu les c n t tally f tw fiber g p unning t ght a gle to ach th a d atta hed t the la t c ut cular plates en lo ng th th r x The th r ic def rmati p od ed l the l ng tudinal h ri ontal muscl reve ed l y nt ct n of the ert al m l and these mus- les tra t alter ately d *ri* g ing m me t The d ect flight m cl s r ng fr m mod fied tu bul leg mu cl in l w flapping pr m ti in ect l k gr h ppers a d drag nfl es i *fil r ll* mus- l fill g m t f th th ax in high *r in ec* F b lla mu les a e m de p of large f *le* up t 1 8 mm *n d am ter They* re ft e lored y ll w r p k f m h gh c n e tr t n of re pirat y en zyr s These fiber l *e t l* rge b dl f fibr ls nd c ntain many i gularly placed clei d g at n mbe s f large m toch nd a or rco- *mes* The l tter a e th e t f the e zym s u d met bol m

S p rmp ed n the flapp g m t n f th w*ngs* cha g n w ng ngl t the t p a d bott m f a h w g t oke The e a g il r changes re e s n *t al* ht i i g a r lt nt f ce of l ft nd f r wa d th u t fr m the flapp ng m ti n The wi g m em nt an b l kened to a hel c pter w th o l l r t d f r tat ng bl de Changes *in* w ng *angl* b ght bo t n pa t by the compl wing i th t n t th th a nd n part by the pull f m ll mus l s att ched d ectly at th w ng ba Th d ect flight m cle nabl many ect t h er fly b kw d *and make* t ght tu by ct g d ffe nt ally on th wi gs

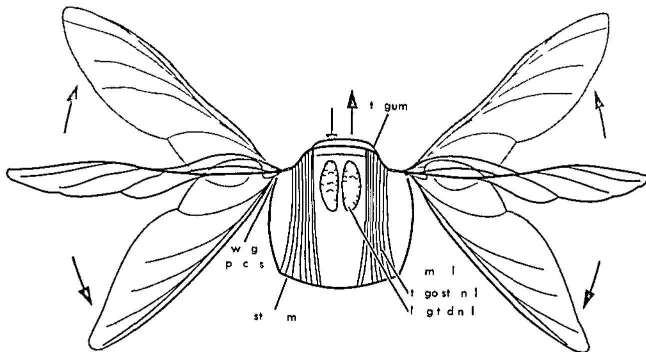


Fig 6 W g movements in the fl ght of an i sect (From T I Storer a d R L Usi ger General Zoology 3d ed M G aw H ll 1957)

In in ects with two pairs of wings the hindwings flap in air rendered turbulent by movement of the forewings and their aerodynamic eff ciency is thereby impaired In the butterflies moths bees and wasps the hindwings have become reduced in size while in the flies they are lost They may be coupled by hooks to the forewings so as to produce the effect of a single moving air foil In beetles the forewings (elytra) serve only as covers for the hind wings which provide the power for flight

A unique characteristic of insect flight is the high frequency at which the wings may beat This ranges from 5 beats per second in large butterflies to as high as 1000 per second in small midges Most gras hoppers dragonflies and moths have wingbeat frequencies of 15–50 medium sized flies 100–200 bees 200 300 and mosquitoes 400–500 per second Since the indirect flight mu cles con tract and relax once during each beat the higher frequencies imply an unusual muscular perform ance

With a few exceptions insects beating their wings le s than 50 times per second have flight muscles similar in structure and physiology to the tubular mu cle found in the legs and other appendages In the e each motor nerve impulse from the nervou system brings about one muscle contraction and one ensuing wingbeat High frequency wingbeat is a sociated with fibrillar mu cle One physiological pe culiarity of this mu cle i that it contracts a dozen or more times for each motor nerve impul e The e impul es appear to generate a critical tensi n at which the mu cle become un tal le o cillate and does work In other word the rhythm of fibrillar mu cle is myogenic and independent of mot r nerve impul e frequency This o cillatory property of fi l rillar mu cle is not fully understood l ut it de pends upon a critical ten ion generated l y n rve impulses in addition to critical inertia and damp ing of the load the elastic properties of the thorax and in some cases a mechanical click mechani m in series with the muscle and its load When the muscle tension surpasses that of the spring in the click the latter goes abruptly from the up to the down position and the muscle goes suddenly slack This slackening may destroy the mu cle s ability to develop tension thus permitting the click to return to its original position It is not entirely clear how this facilitates the oscillatory behavior of fibrillar muscle A click seems to be in olved in the flight mechanism of some flies and in the ound producing system of cicadas In the latter a stiff convex membrane (tymbal) is vibrated in and out 100–500 times per second by a fibrillar mu cle attached to its inner surface

The air speeds of insects rarely exceed 15–20 mph although some dragonflies may reach peed of about 50 mph for short periods A tethered fruit fly is capable of 2 hours continuous flight and 1 500 000 wingbeats l efore exhaustion Tethered lo custs are capable of 5–8 hours of unbroken flight Little is known about the di tances free flying in sects can tra el nonstop Fa rable winds are un doubtedly resp n ible for reported trips of se eral hundred miles

The immediate energy source for short fligl t is sugar An exl austed fruitfly is capal le of f rther flight within 30 sec of feeding on sugar solution Fat re erve are drawn i p n during the longer flights of locu ts Bees may f rage e eral miles for nectar which c ntain i p t /0 sugar Long trips are uneconomic howe er in e m t f tl sugar is u ed in fueling tl e r turn flight

The energy expenditure duri g fligl t r acl e 2000 kcal/kg of mu cle p r h ur 10 tim tl at f human heart mu cle an l twic tl t alculat d f r

humm ngb rd fli ht Sugar i oxidiz d with n ind r t flight muscle by enzyme c nta ed in the nu mer s mitoch nd ia The xyg n on umption dur i g fl ght m y b 50 t mes th t when at rest and the temperatu e n the th rax may ri e 10–15C above the esti g temp atur

Fl ght can be in tiated in mo t insects by l s of co ta t betw en the feet d th gr und Light i t n ty flicker odo s and the relati e w nd pa s- ng er th e t body all play a part n ma n ta ni g nd stee ng fl ght acti ity Stab l zation of p t h d yaw t nd nc du ing fl ght s s i ted by inert al r gy o pi torques cting o the mov able he d of d ag nfl es the h lte es of fl es and p bly o otl e ppendag s *See* FLIGHT

NERVOUS SYSTEM

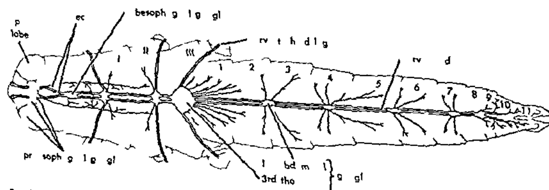
Th s ateg ry nclud s the n rve mechan sm of *tran m on a d integ ati n ly ng* between the s n rga s and the mu l s or gland Th nerv ou ystem ca not p pe ly be con idered apart f m th i p t and tput y tems s n e they pro- ide th pathways int it fr m the uter world and the m whe by t act ty exh l ted a be- h i H w r the nerv u y t m *does m h* m r tha me ely c ect ens o gans nd mus- cl Th s illu t ated by what may b called its pe m e p p rty Throughout l fe the n rv y tem s bomb ded by c nt u but fluctu ti g b rr ge f en o y ners impul e f om ma n g s y t nly a mall pa t f tl put be le rly trac d t utp t n the form f beha i r l respo S mil l th nerv s y t m s co nected w th all k l t l m les y t *Jn po e be* ha al e p n e m d p of h gl ly e tr ted p tt n and seq n e f m le ontra t Th the perm ive q l ty f the ervo sy t m c b l k n d t r hip r l m tat on f th p ad of rv ex tat to p fi p thwa

In ert r well s ted for tud of l h and th p bl m Th r b ha to th gh c mplex f pu tly f ll w t eotyped a d i born patte n M t of th rvo *sy tem lik that* of the in rteb at p ead out n a h i of ga gl a ly g l i th e tr l d f the b dy O l the bra n is dor al ly ng in the l ead in close c ntact w th the eyes and antennae Ea h pair of ventral gangl a i a emia ton mou center f r the n e organs and mu cle f it body s gment Long tudi nal conne t e j in gangl a and l rain to provide pathway for the integrati n of their separate ac tivities into a unified pattern of behavior

Th ee general approaches l a e pro ided inf rma ti n on the phy ology of the nerv us sy tem Th surgi al approach or ablati n draws conclus on f om the change in beha ior that f ll w the cutting of nerv r the r m val of part or all of specif c gangli The electrophy l g cal appr acl aims to i olate and t map *in detail specific e nts in n ural t an mi n a d integration* Th *method* dep nds ip n preci stim lat on of nerves and upon detect n of the lectrical sign of nerve ac ti ty The b havi ral appro ch lea e *the animal* i tact and ob rves its react ons t mea ured en i ronm ntal changes *See* NERVOUS SYSTE I (INVER TEBRATE)

Ablation Th urg cal appr ach g es back to the anc ent Greek who n ted the abil ty of a head less in e t to p rform many c mplex acts It h s re ealed th following facts about the in e t nervous sy tem A s ngle i lat d body egm nt bear ng a pair of l gs is capable of a ariety of respo e Th se n lud gra p ng by the feet when they en ount an obje t w th drawal of the l g from a xi us t mulus alternat rhythm c leg move- ments a in walk g and re piratory m vem nt Some of thes act itie are mo inten e after neu al is lat n f segme t others are less so Oth p po e a t n that may l e c ntin ou in isolated s gm nt or groups of segm nt are c pu latory mo m nts in the pray ng m nt egg lay ng in a n mber of in ect nd th sting ng mo ement of bees

In the intact in ect thes a ti t e tak their pr pe s quence in the total p tte n of beha ior th ough the a t on of exc tat ry and inhibit ry rvou i flu nces r hi g the local g nglia f m the bra n nd oth r ner e c nt rs Th s leg and f ot mo ement a e coo d nated in the six legs o a t p od c fl ti locomot by en ry nd



Fg 7 G h pp rv y t m d l w (F m T I Sı d R L U g G f Z l gy ... w-H ll 1957)

nervous interactions of the three pairs of thoracic ganglia The brain in addition to serving as a receiving and coordinating center for the input from eyes and antennae determines the pre ence and direction of locomotion by a combination of excitatory and inhibitory neural actions on the thoracic centers The local activities of copulation egg laying and stinging are suppressed most of the time by higher nerve centers and only released and steered by them under appropriate stimulus situations The mechanisms of posture and stance due to a steady contraction of certain muscle groups have much the same origin in semi independent local nerve mechanisms subject to coordination and regulation from higher centers

Electrophysiology The electrophysiological approach depends to a greater extent upon a knowledge of the finer internal structure of the nervous system this is information that is much needed concerning insects Sense cells just below the cuticle send nerve fibers (axons) into their segmental ganglia Axons from motor nerve cells within the ganglia leave the nerve cord to terminate in muscles and glands Internuncial nerve cells within the ganglia connect ensory and motor nerve fibers in a dense central region known as the neuropile Points where sensory fibers influence the activity of internuncials and the latter in turn influence motor nerve fibers are known a synap es

Nerve impul e tran mi ion along in ect axons is basically the same proce a in other animals Each impulse appears to be a digital event with a high safety factor Special giant fiber ystem with axons as much as 40 μ in diameter (large t mammalian axons are 20 μ in diameter) are concerned in rapid respon es such as e cape from predators although most insect nerve cells are about the same size as in larger animals It follows from this that the total number of nerve cells in the in ect nervous system is considerably le s than in vertebrates and even large muscles such a the jumping muscle of the grasshopper are supplied with only two or three motor axons

As in all animals synap e are important as limiting mechani m in the nervous ystem becau e of the greater in tability of impul e tran mi sion from one nerve cell to another as compared with impulse tran mi ion along an axon Synaptic tran mi ion is readily modified in vari u way by previous activity and by changes in the chemical envir nment of the nerve cells concerned An imp il e arri ing at a synapse may excite or inhibit the recipient nerve cell or it may modify previou acti ity or influence the re pon e to impul e arri ing o er parallel synap e For the e and other rea n ynap e undoubtedly play a maj r part in the permi i e properties of the nervou ystem

There is trong evidence that recipient nerve cells are acted upon by chemical ub tances or mediator relea ed at the ynap formed by impinging nerve fiber Acetylcholine identifed at ynap e in other animal appear t be the media t r at me in ect synap e Nic tine is toxic to in

on their synap es A large do e of nicotine acting generally on a number of synapse erve to upset the permissive properties of the nervous ystem and cau es general mu cle pa m An important group of modern insecticides the organopho phorus compounds inactivate an enzyme in nerve ti ue whose normal role is to destroy acetylcholine as oon as it action at the synap e is completed Per i tent acetylcholine at the synap es cau es di coordination and spa ms

Transmission of nerve impul es along axons and at synapses can be detected as electrical changes These electrical changes are due to rapid ma s movements of ions particularly odium and pota sium along diffusion gradients acro nerve cell membranes It follows from this that critical concentrations of the e ions in the fluid urrounding nerve tissues are of ome importance Since the concentrations of the e ions in the blood may fluctuate with diet the ganglia and nerves of in ects are separated from the general circulation by a pecial heath that appears to regulate the penetration of alts and other substance into the nervou ystem

Behavior It is impo sible to make many generalizations about in ect behavior ince the acti ities of in ect are a varied as their body form The most that can be done is to point out a few fact of in ect biology that provide clue to the kind of behavior likely to be encountered

Insects living in temperate climate are e entially seasonal in their activitie The egg of a pecies are all laid at the ame time of year and one to several generations in which all the individual of a population are at ab ut the ame de elopmental stage are completed in the cour e of a ea on This means that in mo t in ect there i little or no contact or interaction between immature tages and adult and that each stage with it own specialized way of life may last for only a few day or week

Thus the nature of mo t in ect life cycle lea es neither time nor opportunity for behavior pattern to be acquired through emulation of experienced individuals Thi mean that mo t of the highly complex beha ior pattern a ociated with orientati n f raging feeding and reproducti n are a innate and ine itable a i the unf lding of body form which appears complete in all detail as soon a there is coin iden e of the appr priate developmental tage and the r lea ing timulu ituati n The adapti e perf ti n and beauty of the elab rate eq ence of action made by f raging wa p and bee tempt speculation bout f re ight and intelligence but there is no e iden e that the e actions are determ ned or g ided in any way ther than that een in the dev l pment of a p ttern of colored cal on a b tterfly wing

Th inevitab ility of m t in e t beha ior d es not mean that in e t nn t learn In fact learning and memory of a high rder ar part of many be- i r pattern in b e a d wa p

In many artif ci lly d igned ma e in ect learn sl wly a l sh w p or r t nti n H wever s litary wa p ha e a triking apa l arn th

raphy a d landma k of the for g ng ter it ry b ing able to reor ent th m el es immed ately when tran p rted t noth r pa t of t in a darken d box A w ker honeybe ret rn g to the h e fr m a rich ource of nectar not only emember and i able to r tra e t path but i bl to commun cate by me n of a d n e the d tance and di ect n f the food so ce t the wo ke s within th d k ned h A th r learn g proce s f m inter e t i p im g n l nd t on ng In many in e t the ite cho en f r gg lay ng highly pec fic Thi may b a sp i l food pla t r in pa f rm a part l r h t pe e Wh n tl t me l ght lat t d in th choi e th female may be in fl en ed by the odor of th particula food up n wh h h w s nou hed a larva

E amples f in e t ntat on h ve be n gi n in th e t f th t cle on en e organ O ent t mech ms rang f m s mpl turning toward away from a stimul uch a n hem l t ap l ght, or oth infl n) to the comple l ght compa o i nt t n ed b b e arts and w p n th e f ag g e p d ti n Thes n ts na gat w th m pre i i n over l g d tan by m ng at a fi ed a gl to th un r ts p la zat patt rn For interval f m e th n a few m nut b tween for g g tr ps this type of igati n bj ct t an err r d t dis pla m nt f th un from t t west H wev r th e nd ma y oth in e ts appear t ha e a bu lt t me en that p rm ts them to c npen t f nd pl eme t Th tim en e i m n fest in othe way B fed h f ects l tw en 9 nd 10 m w ll eappea p mptly at the am p t 24 h urs lat en when the ual sola c a e la king If b tw n th fi t a d c d feed g the h mo ed t n nti ly tr ng a ea the bee t ll t k th rigi al com pa b g f m the hi nd e rch at the co re t d tanc at the p op tim f day

A tim e al man f t th daily acti ty hythm f nd n m t ects F in ta e ock oa h s m e about h f food at n gl t and g th a tiv gr up du ng th d y If sol h g h lte at n of l ght a d da k e el m ted th 24-h r t tiv cy l p rsi ts f me time S mila d l rhythm of e gr at fi ty fo d n m ny the a m l

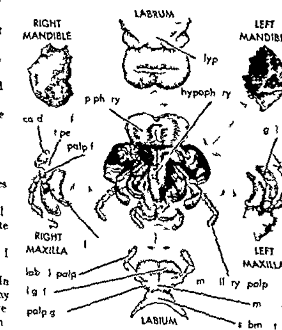
Mo t n ts le d a sol tary l f a d ther littl nt r t on betwe n nd duals f spe es x pt fo m t ng I rni s f m the m le l kely t be tt ked a d e t t th t me al th gh p c al l me han m elab te c u tsh p beha i may ea e the han es f f rt l t b fo e th male i c med Th oci l ect u h te m t s ants bee and w l p e nt th th r e t m of this tuatio In them th o l h l t i blig t y th wh l col ny be g d i ed f m nd d pendent po the re p od ng di id l r qu n Nestm t re gn t nd l ny oh r ce e det rm ed b an od r c mm t all m mb and un q to th l ny Th ub q ty f th od det m ned ap p tly by th food i k f th ol ny s a ed by f qu nt act of food regurg tat n and exchange betw n i d vid l Intruder from an th r c l ny are immed ately attacked alth ugh para ites within th n t may b able to ac ju re th i od r and tl go unm le t d See SOCIAL I ECT [K D R]

B bl graphy K von Fri h *B es Their V is on Ch mical Sens s and Language* 19 0 G Hoyle *Comparative Physiology of the Nerv us Contr l of Muscula Contracti n* 1957 J W I ringle *Ins ct Fl ght* Cambridg Mon graph in Expil B l 9 1957 K D Roeder (ed) *Insect Phys ology* 19 3 V B Wigglesw rth *The Prin iples of Insect Physi logy* re ed 1953

Insecta

A clas of th phylum Arthr pod som t me called the Hexapoda Th s i the largest cl f animal contain ng about 1 000 000 d cribed pecies l it the e ar po sibly a m ny a 10 000 000 act al spec es of n e ts Like oth r arthropod th y l a an exter al ch t us co ering Th e l dy i d ided into serie of rings or gme t wl ch d ff r fr m th e f all other arthropod s nce the g ments a e u ually arra ged in three di tin t g i p I ct ne e po e m e th an three pairs of leg a d m t pecie ha e w g The integ ment i compo ed ba ally of a comple l t nce alled l t n wh ch may conta n ther s l t nce th at giv it c lo and stiffn The e ther s b tances of a p ote eo nat re are g nerally d po ted in d s tinct ea c lled sclerites Scler tized are are d m rcated f m other s m lar a e by memb a nou *lin s r ler l to s it r S* ARTHROPODA

The cla ificat on of in cts is ba ed n th p im tiv presen e o ab enc of wing F rm wh h re



Fg l M d b l s m thp rt f the g h ppe (F m C L M t ll W P Fl t d R L M t ll Dest ctiv d U S l l cts 3d d McG w-H ll 1951)

tain the primitive condition of winglessness are placed in the subclass Apterygota which evidently descended from winged ancestors in the subclass Pterygota There is a difference of opinion as to the number of orders of Insecta Some authorities recognize as many as 36 others less 30 would be a conservative estimate Each of the items cla sified in the outline will be found as a separate article

Cl Insecta
Sub l Apte yg ta
O d P otura
C ll mbol
Diplu a
Thysanura
Subcl s Pt ygot
D vis on H m m t bola
O der Orth pt
Dermapte a
Plecoptera
Isoptera
Emb opt
Od n ta
An sopt
Zyg pt
Ephem pt
Mall ph g
Anoplu
Psoc pt
Z pt
Hem pt
H m pt
Thy n pt
D *on H l m tabola*
O der M copte
N opte a
Lep d pt
D pte
S ph n pt r
C leopt
Hym n pt

ANATOMY

The head thorax and abdomen are the three main divi ions of the insect body

Head The head bears the mouth and associated appendages as well the antennae and eyes The mouthparts are composed of four closely united tructures the labrum (upper lip) the mandibles the maxillae and the labium (lower lip) The mandibles are heavily sclerotized structures which crush the food The labrum co ers the mouth opening while the maxillae manipulate the food and the labium covers the under surface of the mouth Within the buccal cavity or cibarium is a tongue like structure the hypopharynx Basically the e mouthparts are modified for chewing however there are various departures from this type among insects

Various glands discharge their contents into the cibarium The most important are the salivary glands lying in the thorax and opening internally through a common duct at *the base of the labium* These structures which produce the salivary secretion are of great importance in those species serving as vectors of di ea e producing organisms The best known product of these structures is the silk of the silkworm

Antennae The antennae which u ually consist of several segments are very slender organs attached to the head in front of and between the eyes They are present in all but a few insects even though sometimes reduced to vestiges of a single egment. They are the principal organs of mell but in some insects they have an auditory function and probably have in all insects a tactile function

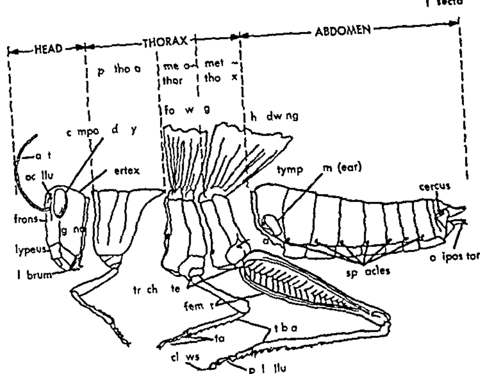
Eyes Two kinds of eyes occur compound and simple The compound eyes are commonly large in some insects they compri e the greater part of the head but in others may be small or lacking They are composed of from 1 to an estimated 28 000 facets of clear epidermis each with a light sen itive structure beneath it Each of the simple eyes, known as ocelli or stemmata has a single facet overlying the light organ There may be everal of these in some insect larvae but adult in ects never have more than three

Thorax Usually connected to the head by a di tinct membranous neck the thorax is compo ed of three segments that are quite closely united but generally recognizable The first of the e the prothorax is commonly the most distinct and bears one pair of legs The second and third called re pectively the mesothorax and the metathorax each bear two legs and two wings Generally these egments are quite closely united to form a sort of box which carries the mu cles for the legs and for the wings The wings are always undeveloped in immature forms and the legs commonly so

Legs The legs are divided into six sections or segments The basal segment or subcoxa is flattened and expanded It forms the side walls of the corresponding segment of the thorax The second segment the coxa forms at times almost a true ball and socket joint with the subcoxa thus permitting movement in any direction The third segment, called the trochanter is very small and quite often is divided into two parts The fourth segment the femur is invariably the largest and longest The fifth the tibia is shorter The tarsus the next segment is commonly di ided into five or less smaller parts with the terminal one commonly bearing a pair of claws All the parts are actuated by a common muscle The legs are modified in many ways for swimming digging running crawling leaping or clinging to the hairs of other animals Although some parts may l e absent legs are always formed upon the basic pattern described

Wings In many respects wings are the mo t important structures of the adult insect body (except for mayflies immature in ects do not have wings) The way in which wings develop is one of the bases for broad in ect classification into orders familie and even smaller groups So precisely are they associated with particular groups that an insect can *frequently be recognized on the basis of a single* detached wing Knowledge of fossil in ects depends largely upon the wing because they are among the more readily fo ilized parts f the in ect body

Wings may be likened to cellophane sacks that are pre ed flat at maturity and which ha e wires in the opposing surfaces t stiffen their structure All cellular structure und rlying tl e surfaces has



F g 2 Outl f b dy f g asshopp l t l w D sf ct d U f I I ct 3d d M G w-H II (F m C L M i If W P Fl i d R L M i ff 1951)

b e l m t d W g b g n t f rm i the imm t r in ect f om a gr p f ll en lo d by th ck a d t i th body w ll Th s ck (t elf a ll t t) app n th s bles rfa e l the body th o- ll d E pteryg t th E d p- teryg t th a k s l d b th the de m u t l c ta st g n d lopm t ched W th the k th ell m lt ply thro ghout g th of the sect They e t ely ns med n the p d t f th wall d th ta n d bl d i withdr wn t the fi al m lt wh th walls fl t t o tt f rm th p f t w g

Th w es th wall f th wi g the rvu e s r fa d d wn n gl b s patt rn h h mm t ll n t th ugh p ble of i fi t t det l M b f the l s fi t n f i se ts depe d on th a tio and k wledg f th m n t t tes a m j r equ reme t f r ect t x m t.

Abdomen Th th rd ct of the n t body th bd m ts b lly of 11 gme ts Al th gh th mb ft ed ed p ally at th p t r d f th body t ne r ed Th app d g leg f thes gment a e p s- t ly t ges the embry s pt n the t mi l gm t wh th a e c n ted t g t l the tr t s that u d the ge tal p n g both the m l d f mal d a m h mpl ed by p ese t d y e t m l g st t d t g h u p f ects

A g t l t u t the f m les the o ip t egg pl c g pp at Ge t l ary de bly f rm d m y be l ck g i me gr up Th y re mod fied a the sti g among the bee and wa p and in ert in para itic relat es f b es and wa p's may f rm an rg n l nger th n the body fo dr lling into wood In some r lat e f g a h ppers gen talia tak th f rm of bladel ke tr ct res as lo g a the body

In the mal th e truct res a e modifi d in many strange w ys to fo m orga s f r gra p g the body of th fem le a d for penetrati g the l a These org m y be the e ti ly exp d or re- t a ted int the b dy f the male except when in u e

Respiratory structures All i ects e cept pos- ibly a f w of th ery mplest f rms br the th gh a ystem f tube which a e i ag nat f th derm d wh ch mify thr ghout the en ti b dy Th e tubes a e c lled trache e d their p gs t th e ter or called sp acl The t bes end in mi ute t h l which penetrate mong o nto the d d al ells of the body t u There a e ne r m e th 10 pa rs of pi r les i any i ect A p b rne o ea h f the fi t 8 gm t f the abd me and l ea h n th m thor x a d metatho a Th s numb r is re- d ced to as few as 2 pairs on the thorax i me spec es I many aqu t c f rm th spiracl s a e r pl ed by gill whi h m y ccu on alm t ny p rt of the body The m m t f g s s th ough the t a he l system is c t lled ther by body mo em e ts f p mp g n t re by d ff on f th ga th ough th p cles or g lls Th final t a sfe withi tl body th funct n of the tra cheole

INTERNAL ANATOMY

The internal structure of insects may be consid ered in its five major aspects dige tive excretory circulatory nervous and reproductive systems

Digestive system In ects posses an alimentary canal extending from the mouth at the anterior to the anus at the posterior end of the body This canal varie in form from straight to convoluted It begins with the buccal cavity or cibarium con tinues through the pharynx which serves as a gate way and sometimes as a pump for liquids and on through the slender esophagu which may expand into the crop The crop in many forms is lined with teeth for further grinding of food Next in or der is the proventriculus followed by the cardiac valve leading into the midinte tine where the prin cipal proces es of digestion take place The open ings of the excretory system are at the po terior end of the midgut The canal narrows to form the short inte tine and then widens again to form the rectum The anal opening morphologically is on the eleventh egment of the abdomen

Excretory system The excretory system con ists of from 2 to as many as 150 tubules called the Mal pighian tubules They generally discharge into the po terior end of the midgut or into the begin ning of the small intestine In some instances they are much folded and thus longer than the body it elf

Circulatory system The blood propelling or gan or heart is a single blood vessel called the dorsal tube that extends almost the length of the body Blood is taken in through openings or ostia in the posterior region of the heart is propelled forward and then discharged at the anterior end after whi h it flows freely through sinu es of the *body cavity finally to return to the dorsal tube*

Nervous system The ner ous system consists of a pair of nerve cords usually clo ely united as a single cord and extending along the ventral side of the body cavity In the e cords are swellings called ganglia Typically there is a pair to each bod g ment but this number may be reduced by the fu sion of ganglia The two cords eparate in the head to pa s around the alimentary canal thu forming the e ophageal commissure They unite again as the suprae ophageal ganglion or brain which is formed from the fu ion of ganglia of all the eg ments of the head From each ganglion of the chain nerves extend to each corresponding egment of the body and also extend from the brain to part of the alimentary canal There are everal minor gan glia connected directly with the brain

Reproductive system In the female the repro ductive sy tem consist primarily of a pair of ova ries each with a number of tubes called ovari les The ovarioles from each ovary unite into a common tube and the two tubes fuse to form the oviduct. This discharges through an external opening the vulva located on the ventral side of the eighth eg ment There are special glands and other chambers that open into the oviduct The germ cell forms at the inner end of each ovariole and pa es through a series of chambers receiving it supply of food material as it proceeds In the la t chamber it re ceives its chorion or shell which has a minute opening the micropyle As the completed egg pro ceeds into the oviduct it pa es the opening of a chamber the spermatheca where perm previou ly received from the male is released to enter the egg and cau e fertilization The other gland may at this point contribute various substances u ed for attaching the egg to a sub trate or for covering it

In the male there are paired te te in which the sperm are formed From the e a pair of lender ducts called the va a deferentia unite into a com mon ejaculatory duct and this extends into a vari ously sclerotized penis The sperm is commonly *stored in swellings of the vasa deferentia* to a sit copulation Connected with the e structure are var ious acces ory gland

Among the many groups of insects various modi fications exist in the e basic structure and in their

Fig 3 Sag tt l sect on of a cock oach show g i t nal a tomy (From C L M l alf W P Fl t and R L M t alf D tr t a d Us f I I s ts 3d d McG aw H ll 1951)

m thod of per ti n In f ct almost ery method of eprod cti n that s kn w in th an m l ki g d m c be f und am ng the i ects Cop lati n n rmally cc rs thr gh th vul l t n the bed b g fam ly C mi ida f the rde Hem ptera it t kes pla e by m an f a pec al tructure occur g t a us p nts on the f male body The p rm i ece d thi tru tur d th n p s ed th ough the body a ty to fe tilize th egg n the a le I me in ect the p rm mu t pass thr gh th o iduct i t the o ar le to fert l e th egg b f t enter th id t The f rtil zed m mat r gg d l p t matu itv in the ova i le In some f rm th le r n t tul ular but a e h ped l k b n h f grapes In a few nse t the mbry i r t i ed with the b dy unt l it i fully g own, b ng n u h d by gla dular ecret ns Th r e som th g f pl c tal de elopment some f m fi ct

METAMORPHOSIS

After b i g hat he l r born n t t only i r ze b t they hang in f rm to some de gr i th m j rity to an xtra rd ary e te t The e n i e m r ly gr wth Th h nge i f rm i l es the mo e el b r te pr c es c ll d m t m ph I t ha b n gr uped or las fied o the b sis f the type f metam rph s s th y und g utl n d b l w

1 Am t bol p mt n d t n t e t nal b n e e d t with n n re e n ze Met bol u d t nct chang s both in s e a d f m a e d nt

P u m t bol d ct m tam ı h that is mpl a d gr d l imm tu f rm e mbl th ad lt e ept n e and r re f d t ymph

b H m m t b lou m tam pho nc m pl t g ll ar p nt n quat c larv e, a d

H l m t bolo mplet or ind ect m t m ph s s t g n th s d elopm nt are th gg l rv pupa nd ad lt r m g

T a i i tk n t mu t l ak th gh the lat ly nela t d rm l ov g Th is d w th the d f rta n h rm n as f ll w A w k n t i g y h g l d d w d rn th th ld Wh n th ew k n ompl t th ld pt r d th t t kes water i th al m nt y l n n and p i ut Th s molt ng ecdy The new k at fir t wr nkled d f lded ema n ft and fl x bl l g ough t ll w th b dy t xp d t t fullest t t bef e h rden g ga n By h ed f th dy s, th fi l f rm

Ch g f n s e d nt ly at time f m lt g l t l lee p p d nt r lly b f ch m lt In th u f th r us m lt ll the h ng f m the l h t h d mbry t the f ll f med ad lt n t ke pl In som f rm th d lt d ff fr m th ymph l t ge nly n ha ing w ng and e ternal genital In the a t ma jo ity h weve the metamorphosi i c mplete and the ad lt f rm n no way re mbl le the imm at ire r larval form The immatur stag and the adults h e d erged far from each th r that the tran t on betwe n them i crowded into a ngle t g Externally it appears a a qui t period l ut in t rnally it i a time f inten act ity di ring which th ent re tructure i rem lded Thi per od i known a th pupal tag The larva and the a lilt r imag d ffer n t nly in their tri cture but al o in th ir hab ts whi h usually ha e n th ng at all n c mmon S e INSECT PHYSIOLOGY IN ECTA FOS SILS [C F F]

B bliography C T Br e A L Melande an l F M Carpe t r *Cl s ific ti of I s cts* 2d ed M um Comp Zool B ll 108 19 4 J H Cm t ck *I t odu ti n to Ent mol gy* 9th ed rev 1940 E O F g C ll g *Entom logy* 1942 A D Imm *Gen al T xtbook of Entomology* re e l 1957 H H Ro *A Textbook of Entomology* 2d ed 1956

Insecta fossils

F s il i ects ar th rema n or trace f in ts pr erved in rock They t i lly c n i t in part of an impres i n in th ro k matrix and in part f ome altered rgan c sub tan es m re r rely a in the a fi t pr erved in amber m ga comp und s l h t n may p r i t w th ut h ng I g ne al insect bec me pre erved a fo ils by the l uri l of l ving or fre l ly kill d p m n olt m d wh ch acc m l tes ap dly nough t prevent d s nt gr t on of the in s t Th nt al ha de ng of the m id f rms a edim nt ry rock c nt ning th in ect remai The f s l *in ects are obtai ed* by plitting the r k alon pl ne f depo ti n with a h mmer and ch el See AMBER

Fossil record F ssil in cts ha e b en found in b ut 100 d ffe ent r ck f mat n thr ghout th w rld O e f th best kn wn d pos t s a h le bed n the t wn f Flo ant Col ad In the Ter tiary Period of th e th s h tory bout 50 000 000 ye go th w th it f a h llow lak su und d by a t e volca o A the l fr m th l an es f ll nto the wate of the lake t car ed l ng with it whate e n e ts were flying o r the l ke and the a h ttled on th bottom to fo m mud the n ects w p omptly bu ed The Flo a t hal has y ld d fully 100 000 p ci me f n t (F g l d 2)

Pal o c Th e l e t kn wn f il n cts ab ut 250 000 000 y a ld re fo nd n r ks of Uppe C rb f u (Penn yl a a) age M t f th ea ly i s cts h d pp x mately th si e and ppe e of the li g m yfl es nd drag nfl s to whi h they w l ely el ted A few of th d ag nfl l ke i ts (b lo g ng t o e family f the xti t o d I t don ta) we la ge hav g w ng pr l f 6 m (30 n) Th mo t num o t f th tim at le t i wampy regi w th co kr ches wh ch e mila in ap-



Fg 1 Fo 1 ect f om M oce e of Col d (a) P od yas p sepho Sc dde o d Lep d pt (b) L th myl ol mb a (Co k ll) o de Neu op- t a

pe anc to li ing roa he The early i e ts w re les pecialized than any other known insects and are ually thought to ha been cl e to the an ce t rs of the winged n ects

Th inse t fou d in P rm n rocks (formed ab ut 22 000 000 year ag) represent a far more d ve s fied fauna th n that of any other per od in the rth s hi t ry in luding the p e ent The ex tinct d rs that exi ted in the Carboniferous Pe riod survived int th Permian and n addition ev ral l ing orders were repr sented Along with the hug drag nflylik in ect (Protodonata) w re s ch minute in ects as th bark l e (Psocopt ra) s me ha g wing pread f only 3 2 mm The fos ls how bout an equal represent tion of the ext nct o d r of the Carbon f ou and some r latively sp ci l zed livi g ord rs Add ng to this diversity we e e al ext nct o der not found n Ca bon fe ous strata The li i g rders repre ented i th arly Perm ncl de s h types as the dr gonflies (Odon ta) mayfl es (Eph merida) bark l (P ocoptera) H mipt ra (true b gs) and sc rp on fl es (Mecopte a) Th pr e e of the co pi n flie s e peciall i te e ting nce th l v g specie ha a c mpl cat d postembryon c d l pment haracte ist c f all of th most h ghly peciali ed of l ing in ects True b tle (Col p t a) a d stoneflies (Pl pt ra) appe r in Late Perm an d po it

Mesoz c At the beg nning f th Me zoic Era tl r o d of f ssil n ct chang s significantly Th contrast between the ar h i fa n of tl Ea ly P rmi a d the elati ly d rn one of the Tr s as gre t s tl t b tw n the faun of the T s c and th R ent (pre ent) *periods* The xt n t pr t d n te dr gonflie pe s ted i t th T s c but appar tly di d ut by the end of that p ri d No e f the oth r xt nct rd rs of i cts i f u d in d p ts lat th n th P rmia

The i s ts found i Jur s i strata compr e a fau much l ke that f the Tr a ic ex ept that m e li ing f m l es ar r pre ent d In general s ch fam l es occur in th o de s that we e well developed the Perm an h as the Odonat d H mipte a Not bly ab t the J ra were fl we i ct in parti lar the bee and syrph d flie By th b gi ing of th n xt peri d th Cre t e us th fl w ing pla ts had b ome tab l h d d ll p bab l ty the typ of in cts ssoc at d w th th se plants promptly f llowed Unfo tu at ly nly a e y f w i t a e k w f m C et eous rocks

C o i In ts a mo e b nd nt i Te t ry depo t than n ny the *f rm t o s.* The fo sils h w th t a m h high pe entage of li ng ge ra w s p e nt i Eoce nd Olig e tim than n the Jur e Th p es rv d i B ltı amb wh h s of a ly Tert ary ag a e e p lly mpo ta t n making p s bl th comp r o s th li g ge e nd pecies Exten i st d f mbe i t F ve sh wn that th m nt f ev l t onary ch ge th t ha t k n pl ce s ce th e rly T rtiary a je gr atly w th the p rt cula







Fig 2 F ssi ct (a) H l o p m f Scudde d Mec pt d (b) bb fly o d D pt f om Moc e f C l d ( ) Cl t tt and M K w d Orth pte f m T o of N w So th Wal

fam ly of in cts c ncerned For exampl about half f the nt genera fou d in the Baltic amb r (t tali g 43) are l g genera whereas in th ca e f the bees only ngle amber genus is till li ing Se al sp c es of the B lt c ambe ants are ind t gu sh ble from l vi g spec es

Significance Th tudy of fo il i s ts h s m d s gn fi ant ont ibut n to the unde stand g of th ev lut on of in ct and f the re t onsh p f exi t ng rd s a d fam l s It h b com ap p ent that th g o p n w l *ing* are b t a mall *pa t* f the total numb that ha e e sted on th *earth* A det led tudy of the f s l forms pr v de den f ert in pr gre i ch ng in t uc tı e a d d velopm nt wh ch n the ma n are on fi med by mo pholog al and d v lopm ntal n s

tigations of living insects There is however no fossil evidence bearing on the question of insect origin the oldest insects known show no transition to other arthropods Morphological and develop mental studies however have indicated that the an cestors of the insects were terrestrial arthropods probably related to the Symphyla Although the time of that origin is not directly demonstrated in the rocks the fossil record suggests that it was at least as far back as the Mis issippian Period (Lower Carboniferous strata)

The fossil record combined with morphological studies of living types shows that insects have passed through three major evolutionary steps The first of the e was the development of wings as sim ple but functional outgrowths of the thoracic wall which could not be folded back over the abdomen when the insect was at rest The dragonflies and mayflies constitute the only living order that rep resent this stage in in ect evolution The econd step was marked by the evolution of a complicated wing articulation which enabled the wings to be folded back over the abdomen at rest and by the pre ence of immature stages re eml ling the adults The grasshoppers and their relatives (Orthoptera) the true bugs (Hemiptera) and similar living or ders belong to this stage The third step was the acquisition of a complicated postembryonic devel opment with an immature stage (larva) very dif ferent from the adult as in beetles and true flie The fossils show that insects pa ed through the e stages before the beginning of the Permian Period some 225 000 000 years ago when land inhabiting vertebrates were only tarting their evolutionary history *See* INSECTA [F M C]

Bibliography C T Brue A L Melander and F M Carpenter The cla ification of in ects *Bull Museum Comp Zool* 108 777–827 1954 F M Carpenter *The Geological History and Evolution of Insects* Smithsonian Inst Publs Rept 1953 339–350 1954

Insecticide

A material u ed to kill in ects and related animals by di ruption of vital proces es through chemical action Chemically in ecticides may be of inor ganic or organic origin The principal urce is *from* chemical manufacturing although a few are derived from plant In ecticides are clas ified ac cording to type of action as stomach po on con tact poison re idual poi ons sy temic p i n fumigants repellents or attractant Many act in more than one way Stomach poi ons are applied to plants so that they will be inge ted as in ects chew the leave Contact poi ons are applied di rectly to in ects and are u ed principally to control pecies which obtain food l y piercing leaf surface and withdrawing li juid Residual in ecticides are applied to surface so tl at in ect t ucl ing them will pick up lethal do age Sy temic in ecticide are applied to plants or animals and are al rl ed and tran located to all part of the organi m s that in ects feeding upon them will ol tain l tl al doses Fumigants are applied as ga e or in a f rm which will vaporize to a gas to be inhaled by in sects Repellents prevent in ects from coming in contact with their host Attractant induce in ect to come to specific locations in preference to n r mal food ources

In the United States about 500 specie of in ects are of primary economic importance and l es caused by in ects range from $4 000 000 000 to $8 000 000 000 annually

Inorganic insecticides Prior to 1945 large vol umes of lead ar enate calcium ar enate paris green (copper acetoar enite) odium fluoride and cryolite (sodium fluoaluminate) were u ed The potency of ar enicals is a direct function of the percentage of metallic ar enic contained Lead ar senate was first used in 1892 and pro ed effective as a stomach poison against many chewing in ect Calcium arsenate was widely u ed for the control of cotton pests Paris green was one of the fir t stomach poi ons and had its greate t utility against the Colorado potato beetle The amount of available water soluble ar enic govern the utility of arsenates on growing plant becau e thi frac tion will cau e foliage burn Lead ar enate i afe t in this respect calcium ar enate intermediate and paris green the most harmful Care mu t be exer cised in the application of the e material to food and feed crops becau e they are poi onous to man and animal as well as to in ect

Sodium fluoride has been u ed to control che ing lice on animals and poultry but its principal application has l een for the control of hou ehol l in ect especially roaches It cannot l e u ed on plants becau e of its extreme phytotoxicity *Cryo lite* has found (me utility in the control of the Mexican bean beetle and flea beetles on vegetal le crops becau e of its low water olubility and lack of phytotoxicity

Organic insecticides The e began to supplant the arsenicals when DDT [2 2 l is(*p* chl r phenyl) 1 1 1 trichloroethane] l ecame a ailal le in 1945 During W rld War II the in ecticidal pr perties f γ benzenehexachl ride (γ 1 2 3 4 5 (l exachl rocycl hexane or γ BHC) were di co ere l in Eng land and Fran e The two large t volume in ecti cide are DDT and γ BHC (125 000 000 ll of DDT was produced in the United State during 1957) Certain in ect cannot be contr lled with either and there are ituation and crop where they can n t l e u ed For the e rea n otl er l lorinated hydrocarbon in ecti ide l a e l en di ered and marketed succe fully Tl e in lu le TDF [2 l i (*p*-chlorophenyl) 1 1 dicl l roethane] meth xy chlor [2,2 l is(*p* meth xyphenyl) 1 1 1 trichloro-ethane] Dilan [mixt re of 1 1 l i (*p* chloro-phenyl) 2 nitropr j ane and 1 1 l i (*p* cl l ro-phenyl) 2 nitr l utane] cl l r lane (2 3 4 5 (8 8-octachl ro-2 3 3*a* 4 7 7*a* h xahydro-4 7 metl an in dene) l eptacl l r(1 4 5 (7 8 8 l epta l l r 3*a* 4 7*a* tetral y lro 4 metl a in l n) aldrin (1 2 3 4 10 10 hexa hl ro-1 4 4*a* 5 8 8*a* l xah lr 1 4 *endo exo* 5 8-dim than nap l th len) 1 34

10 10-hex hl o-6 7 ep xy 1 4 4a,5 6 7 8 8a-octahy dro-1 4-endo xo-5 8-d m thanonaphthalen) en d r (1,2 3 4 10 10-hexa hl o-6 -epoxy 1 4 4a 5 6 7,8 8a-octahyd o-1 4-endo e 1 5 8 d m than naph th l e) toxaphene (camphene plu 67–69% chlo- r ne) and Thiod (6 7,8 10 10-he a hlo o-1,5,5a 6 9 9a h xahydro-6 9 metha o 4 3 b n od oxath e- pi 3-o de) TDE i con iderably le tox than DDT but n g ne l is al o l s effecti e It has g ven ut,ta d ng re ults tl ontr l f larv e f s ral m th ho ve M thoxy hl r i e en le s t i th n TDF d ha fou d con ider ble u e in the co tr l f ho fl s and lso of the Mex can be n beetl h ch i n t u ept bl t DDT Re t ct ns ha e be placed on its u on da ry c ttle fo the ont ol f fli d ts umption i decl ning Dilan has f nds m u e n the cont ol f th M xi c n b an beetl a w ll as f s me thrip and aph d Chlo d e wa th fir t ycl pentad en i s t c d t e h mmer i l tat It h s b n th mo t ff cti e hem c l ailabl f r the control f oa he In add tion to l ngthy r du l pr p r t e hlo d ne l po es fumiga t ct n Re- lated h mi l l de hepta hlo ald in di ldrin and ndr They a ffe t ve a n t gra hoppers and pec lly eful f r th control of insect inhab ti g s l To aph e i ed pr p lly f th t l of th c tt boll weevil and othe i ect pest f c tto Th oda i dd t n t sho ing pr mi f r the ntr l of nume us cts als h w p omi f t ll ng numb f pec s of phytoph g (pl nt fe d ng) m tes that are n t gen ally ept bl t hlo inat d hyd ca bon i ect c de

Insect resistance The re i tance of n ects t DDT wa fi t ob erved 1947 n the ho efly B the end f 19 8 2 p e f arthropod had been p ed t be e stant t one r m e inse t c des Among th hl r at d hyd arbon s ti ides tw type of es t n occur On appli to DDT a d its an log uch s TDF m th xychl r nd Dil a d the th r t she cy lod en com p d h hl d h pt l lor aldri d eldr n end i d al y BHC nd to phene In t des a n t m t g i d catti g that e tan e p ee t n a sm ll part f the n tural p pul t ev b fo e p

Ne ly e y e t y th wo ld ex pt m n l nd Ch na h ported the pr en e of r st t str f th h fly l m ny h vily popul ted u b s f the U ted St t t i d ff cult to bt n t ol f a hes w th hl dan During 1957 d 1958 m ny gr wer f ott in the south rn st tes h nged f om t xaphe e d y BHC to rgan ph phoru hem cals b ause f th e tance f the c tt boll w ev l to chlorin at d hyd oc rbon i secti d The d el pment f t f th n magg t e tant t ld n d d eldr n n the t rn Un t d St tes and in Ont u g e ern The dev l pm nt of hlo ted h d oca bon r t m ng e ral pec es of d e-tran m tt ng squ t es i a th at i w ld he lth Th e nt l of typhus in the Far Ea t is at stake now that trains of the l ce tran mitti g the d ea e are resi tant to DDT

Organic phosphorus insecticides The de elop ment f th s type of in ect cide parallelled that of the chlorinated hydrocarb ns Since 1947 about 50 000 o ganic pho ph rus c mpound have been syn the ized in academ c and indu tri l laborat r es throughout the w rld for evaluat on as potential in ecticides Parathi n [*O O* diethyl *O* (*p*-*nitro*- phenyl) pho ph roth oate] and *methyl* parath on [*O O*-dimethyl *O* (*p nitrophenyl*) pho phorothio- ate] are e t mated t have had a w rld production of 20 000 000 lb dur ng 1958

A g eat di er ity of acti ity i found among r gan ph sphoru in ect cide Ma y are *extremely* t i to man and th r w rm blooded an mals but a few how a ery low to ic ty Th *more imp r* tant include tetraethylpyr ph phate Chl rothion [*O O*-d m thyl *O* (3-chl *ro*-4-n t ophenyl) ph s- phoroth oate] Malathion [*O O*-d methyl *S* (1,2 d ca beth xyethyl)] ph phorodith o te] DDVP [*O O* dimethyl *O* (2,2-d chl ro nyl) pl ph te] D azinon [*O O-diethyl O* [? i op opyl 4-methylpy imidyl (6)] phosph roth oate] Delna [2 3-*p*-di n d th l *S,S* bis(*O O* diethyl ph phorodith o- te)] Cuth n [*O O* d methyl *S* (4-o o-3H 1,2 3-benz tr a *ne*-3-m thyl) pho phorodithi ate] T i th on [*S* (*p-chlor* phenylthi methyl) *O O*-d ethyl pho ph rod thioate] Ethi n (bi [*S* (d ethoxyph phin thi yl)]m r pt]methane) EPN [*O* ethyl *O* (*p*-n tr phenyl) ph nylpho ph noth onate] and D pt rex [*O O* d methyl (2,2,2 trichl *ro*-1 hydroxy ethyl) ph ph at]

Schrada [bis(d methyl mi o)ph ph ric n h d de] w s u ique am ng *organic in* ecti id in th t it how d y temic prope i es whe appl d to plants By di ect c nt t it ha relati ly low rde of acti *ity* When pr yed on plants, t i b o bed f om areas recei ng *treatment* is tran lo- ted thr gh ut the entir plant and i metabo- liz d t y ld a prod ct highly t xic t s ch suck g p ts aph ds nd phyt phagous m tes It is electi e in th t it affe t o ly aph ds ngesting ju ces f m t e ted pla ts nd does n t k ll pr d t wh ch d tr y aph d With ch dan it is n w p s ble to p t t the grow g pa ts of plants without e t ng t f qu nt sp aying becau the in ect de is t ansl ated t these gr wing parts wh s with mo t tomach p i *on* or re d ual n ecti ides pl nts o tgrow th protection Seve l chem cal how ng sy temi pr perties have ow re hed c mme ial o n a commercial tatus Th i cl d Demet n [*O O*-d ethyl *O*(and *S*) (2 ethylth)ethyl phosphoroth oates] Di Sy ton [*O O*-dieth l *S* (2 ethylthio)ethyl phos- pho odith te] Thim t [*O O* diethyl *S* (thylthi omethyl)) ph ph od th o te] and Pho dr [2 m thoxy arbo l l m thyl inyl dimethyl ph s- ph te]

Th u f gan ph pl orus chemical f r th y t m c co tr l of an m l pa ites i another f et of i te t D g 19 8 m omme c al p- pl ation of Co-Ral [*O* (3-chlo o-4-*meth* ylumbellif

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(Talp d e) bse t only from So th Ameri a Aus-tral a, and Mad ga ar *See* EUTHERIA MAM MALIA [D D D]

Insectivora fossils

Fo s l i ect ores are referred to two gr up on l ar-cut th th r les well defined Th fi t gro p i c mpo d of in ecti or s in which the in te tin l cecum is la k ng and the taped al art ry th major sou ce of blood upply to the bra n. These are kn wn a the Lipotyphla or In ect o a pr p r All li ing in ect vor s ex ept tl e el ph nt sh e (Mac l d d e) nd tr e sh ew (Typa d e) mo t late Cenozoic and a few early C n ic and po bly Cr ta eou insectivores belong to th s fir t group f e t r The econd group is g n ally more primit ve and is pr marily early Cen zoic n kn wn ccurren e Li ng members ha an nt t nal cecum and th blood supply t the bra n t tl p mitt ely e mple The stapedial rt ry not a import nt as i the lip typhl ns P imate tupai ds and ma ro celidid a e de-end d f m arly repre ntati es of this eco d gr up omet mes alled the M n typhla.

Lipotyphla I tl e Lip typhla the ancestry of the hedg h gs (E i c dae) has been traced b ck t the Oli c e Eura with ut que t n nd still m e prim ti e an esto s h ve been t ntatively ide t fi d a ly a th m ddle Eo ne in the U ted St te Cl ely l ted f rms are known as ea ly th e d f Cretaceous t m These forms r clos to the an e tral M notyphla n known t u tu e Th p n pal h m l d of the hedgeho s h s alway been E s a All but the ea liest ec ord f the fam ly in N th Am c r p nt ab r ra t d ri at f th m r ent al E a i n t ck. The f m ly eve r ached South Ame i a r Aus-tr l a both f whi h wer land duri g mo t of the Cenozo c A id bran h, the D myl da flou hed n th m ddl C z of Eu ope (F g 1)

Th Sol nod t d e nd Ne oph nt dae a e fairly cl sely l ted W t I di n f mil of l rg but ne e th l me h t h wl ke lipotyphla O ly th Nesoph t d e wh s ma n a e f nd n l t Q t nary d po t h e a fo l reco d B th famil ar b l ed t h be ome l ted th West Ind es n th e rliest C zoic M i l nd N rth Am n Ol goc n g r (*Apt rnodus* and others) previou ly th ught to have gi en r e to them are now known not to have d ne so

Shrews (Soricidae) have been traced back to the late Eocen (*Saturnin a*) and prior to that their ance try merges with that of h dgehogs Fo il forms differ l ttle from their m dern counterparts in known tructure except in the exti ct ubfamily Heter oricinae in which the jaw is sh rt and the teeth omewhat more hedgehoglike than in other shrews The fo il record of shrew is primarily in Eur pe and North America

Moles (Talp dae) are known fr m both Europ an and Amer can dep it as early as the beginning of the Ol go ene b t at the r first known appearance the moles were already well diff rentiated De man moles how an appr ach t the hedgehogs howe er Th characteri ti talpid digging humerus is one of the mo t ea ily dentified fo il bone in the con ti ental C no ic rec rd

T nrecs (Tenrecidae) who e Recent representa t es re confined to Madaga car except for the aberrant subfamily Potamog l nae of West Afr ca ha e a poorly known fo l reco d in the early Mio-cene f Ea t Africa Th y are bel eved to be deri a tives of the nce tral Eri aceidae but the details are unknown

Another Af can lineage f probl matical lipo-t phl n is th Chrysochl ridae or golden moles These ha e a Ple tocen record in South Africa and ha e re ently be n found in the arly M ocene of Ea t Afr ca The r affin ties p ol ably lie w th the ten ecs though in eality l ttle i known of the orig n of the peculiar m l like animals

Menotyphla Tl e ec nd les well defi ed group I ect o es r Menotyphla cont ins the li ing el pha t hrews a d tre shrews of Africa and South a t A ia These are primatelike (particularly the t ee sh ews) and ar f equ ntly plac d n th Pr mates by work wh reg rd the hedg h gs as mo e primiti The fo l rec rd f elephant h ew goe ba k to the e rly Mi ce of Ea t Af r ca Two s ppo d tupa ds (*Anag le* and *Anagalopsis*) h e been fou d n tl e middle and e rly C no o of Cent al A ia and a middle Paleocene N rth Ame i n f rm (*E da m nema*) may belong to the T p idea

Six early Cen zo c families are te t ti ely re-ferred to the M otyphla Th L pt ct da (*Ictop D acodo* and th rs) ranged fr m middl Paleo n to m ddle Ol goc e n North Ame ica (Fig 2) Th P nt lest dae (*Pa t l st s Aphron us* a d ther) we la ge q t e f rms known f om th middl P leoce e t th e rly Olig cen i N rth Am r a nd arly Eocene nly in Eur pe The Apatemyida (*Ap t mys Het ohyus* and oth er) w r pe fic ally rode tlike fo ms that rang d fr m th m ddle P le ce e t e rly Olig cen in N th Am and f om the ea ly Fo ne to th lat Eocen Eu op The M xode tid are an oth p fi ally odentl ke g o p onfi ed to th Paleocene f N rth Ameri a The Zal mbdal t da (*Zal mbd lestes* only) occur in th Late Cret



F g 1 Sk ll d l w j w f *Amph h* mid C l p typhl sect vo (Aft J V i)

erone) *O O* diethyl phosphorothioate] and Trolene [*O O* dimethyl *O* (2 4 5 trichlorophenyl) phosphorothioate] for the control of grubs in cattle began Co Ral is applied externally as a spray and is absorbed and translocated to kill the cattle grubs Trolene is most effective when administered internally Dimethoate [*O O* dimethyl *S* (*N* methylcarbamoylmethyl) phosphorodithioate] shows promi e in this area also

Activity of organic phosphate insecticides results from the inhibition of the enzyme cholin estera e which performs a vital function in the transmission of impulses in the nervous system Inhibition of some phenyl esterases occurs also Inhibition results from direct coupling of phosphate with the enzyme Phosphorothionates are moderately active but become exceedingly potent upon *oxidation to phosphates*

Other types of insecticides Synthetic carbamate insecticides are attracting increased interest These include dimetan [5 5 dimethyldihydroresorcinol dimethylcarbamate] Pyrolan [3 methyl 1 phenyl 5 pyrazolyl dimethylcarbamate] Isolan [1 isopropyl 3 methyl 5 pyrazolyl dimethylcarbamate] pyramat [2 *n* propyl 4-methylpyrimidyl (6) dimethylcarbamate] and Sevin [1 naphthyl *N* methylcarbamate] They are also cholinergic

Insecticides obtained from plants include nicotine [L 1 methyl 2 (3 pyridyl) pyrrolidine] rotenone the pyrethrins sabadilla and ryanodine some of which are the olde t known in ecticides Nicotine was used as a crude extract of tobacco as early as 1763 The alkaloid is obtained from the leaves and stems of *Nicotiana tabacum* and *N rustica* It has been u ed as a contact insecticide fumigant and stomach poison and is especially effective again t aphids and other oft bodied in ect

Rotenone is the mo t active of six related alkaloids found in a number of plants including *Derris elliptica D malaccensis Lonchocarpus utilis* and *L urucu Derris* is a native of East Asia and *Lonchocarpus* occurs in South America The highest concentrations are found in the roots Rotenone is active again t a number of plant feeding pests and has found its greatest utility where toxic re idues are to be avoided Rotenone is known also as derris or cube

The principal sources of pyrethrum are *Chrysanthemum cinerariaefolium* and *C coccineum* Pyrethrins which are purified extracts prepared from flower petals contain four chemically different acti e ingredients Allethrin i a synthetic pyrethroid The pyrethrins find their greate t u e in fly sprays hou ehold in ecticides and grain protectants becau e they are the safe t insecticidal materials available

Synergists The e materials ha e little or no insecticidal acti ity but increa the activity of chemical with which they are mixed e pecially that of the pyrethrins Piperonyl butoxide {α [2 (2 butoxyethoxy) ethoxy] 4,5-methylenedioxy 2 propyltoluene} and Sesoxane [acetaldehyde 2 (2 ethoxyethoxy)ethyl 3 4-methylenedioxyphenyl acetal] are two important commercially available pyrethrin synergists

Formulation and application Formulation of insecticides is extremely important in obtaining sat isfactory control Common formulations include dusts water suspensions emulsions and olutions Accessory agents including dust carriers solvents emulsifiers wetting and dispersing agents ticker deodorants or masking agents synergists and antioxidants may be required to obtain a atisfactory product Insecticidal dusts are formulated for application as powders Toxicant concentration is usually quite low Water suspensions are u ually prepared from wettable powders which are formulated in a manner similar to dusts except that the in ecticide is incorporated at a high concentration *and wetting and dispersing agents are included* Emulsifiable concentrates are usually prepared by solution of the chemical in a ati factory ol ent to which an emulsifier is added They are diluted with water prior to application

Proper timing of insecticide applications is important in obtaining satisfactory control Du ts are more easily and more rapidly applied than are sprays However results may be more erratic and much greater attention must be paid to weather conditions than is required for sprays Coverage of plants and insects is generally le s atisfactory with dusts than with sprays It is be t to make du t applications early in the day while the plants are covered with dew so that greater amounts of du t will adhere If prevailing winds are too strong a considerable proportion of a du t will be lo t Spray operations will usually require the u e of heavier equipment however Application of in ecticides should be properly correlated with the oc*currence of the mo t susceptible tage in the life* cycle of the pe t involved *See* Entomology Economic Fumigant Insect control biological Insecta Pesticide [C A H C F L]

Bibliography R L Metcalf *Organic Insecticides* 1955

Insectivora

An order of mammals including such familiar forms as the hedgehog shrew and mole The In ectivora are of ancient origin and are difficult to define they are united l y primiti e character th t for the most part are primiti e for all placental mammal It i quite p s il le therefore that se eral stocks of primitive mammal of di er rig n are included in the rder Many fo il in cti ore are kn wn some g ing l ck a far a tl e Creta ceou The order i u ally di ide l int 8 super family group 3 f which are e tin t l iving in s ctiv re are divi led into (1) the tenre an l tl eir relati e all Madaga an ( ) th g l l m l of South Africa (3) tl e l dgeh g (Erinac i lae) and their relati e f Eur p A i nd Afri a (4) the el phant hrew (Ma r l li la) f Af rica and (5) tl e hr w (S ricı la) an l n l

Th table hows that the latit dinal gradı nts of solat on are appreciably smaller at the earth s s fac than at the out d of the atmo phere Th h gh value of urface ıns l tıon near latitude 30 N s due n p rt t the small cloud ness ı the la g h gh pr ure areas at tho e lat tudes Add t nal l g tudin l ar at ons ın ı latı n depend on cl udı Th s n ar l t tude 40 N n umm r th a r ge latı n ex eeds 100 ly/day ın de t r a d fall to 250 ly/day ın th loudy a eas off J pan

Th energy ab o bed at th urface depends al o on the fa e albed Th reflect ıty l the sol d earth es with gr und o e Fo e t ab b nea ly all the en gy ın ıdent them Fresh snow n the ther ha d refle t up t 90% of the ıncı de t n rgy In middle l titude snow albedo may decr e to l than 40% with t me e pec ally after wa m spell l a mod fi d the su f ce G a s fi ld and oth r surfac will ha e ınt rmediate al bed

The r fle t ıty f the wate su fa e of the arth with cl dles kies dep ds t ongly on the s n z n th angl Z The lbedo f r the dı ct sol r beam s o ly 0 02 f Z = 0 nd 0 13 f r Z = 0 It n ea s t 0 35 f r Z = 80 nd t 1 00 for Z = 90 F r the e larg r l e of Z the w nd may c the albed t de rea An albedo value f 0 17 f r Z = 80 with a w d of 15 knot h s bee sugg ted

Wh n ll th f ct s re ons dered the ab rp- t by th atm ph r and e th o f a be est m ted s h wn ın th l t l ne of the f reg ıng t bl It ı ınt e t g to t th t th gr dıe t f bs bed ad at wh h the drı ng f rc f the l t mıl r to the grad t of the ext a terrestr l ı l t [S FR]

B bl g aphy F A Berry Jr E B llay and N R Bee (ed) *H db ok of Meteor logy* 1945 S Fritz, S l r ene gy n l r a d cl udy d y S ı *M nthly* 84 55–65 1957

Inspection and testing

Comm r al p a tıc ı to spect prod ts for tw d ha t t nd t test pr ducts fo p f rma As s h ın p t n a d test g re t p n q l ty a r e whı h t ın may be a t p qu l ty t l

I p t n th e t cal m nat n f p d t t d t m e t c nf rm e t appl abl q l ty tand d r pe ficat on A a r ult f n p t n th p d t ıs th r pt d o r j t d d pend g t degre f c f man Be a n p ct ı a po t mortem p ratı t has ffect th qu l ty f p od ts the ın pe t r m ely a pt o j t p odu ts f th am q l ty hm tted f n p t on

In pect n an h wev ers s the fir t t p a p g m t ma tan l ed qu l ty l l (*see* QUALITY CONTROL) A m ll p t n f the prod ct n pected soon s t ı mpl ted th res lt l ed a d pp p ate t n d t rm n d t ad j t th man f t r ng p r t so a t m ı ta the desired quality It ıs this control or continual adjusting of the process whı h assures the produc tion of pr duct within applicable qual ty restric t ons In th s ma n r any de ed level of quality can be ma nt ned and the product on of subquality items can be prevented

Howeve the need a ı es to evaluate the quality of p oduct after they ha e l een m de and ıt ı no longer po sible t e ercı e control o er the produc tion p oce s Q al ty a uran e fill this need Q ıal ıty as ur ce ıs rel ted t q alıty c ntrol but ıs not synonymous with ıt Quality a s *rance operates* after qual ty control when the product ıs com pleted It u e *ınspectı n and te ting to evaluate the* quality of prod cts and to determın th degree of conf rm n e t applicable standard

In *pection* ıs generally a mechanical operat n ıt determ nes the adequacy of such characteristics as appearan e d me ı n and o er all operation of th p oduct Test ng ı more penetrating ıt me su e p rforman e ın ne f rm or another Test ng ı olves ı trumentation to *mea ure the* function l adeq cy of the product Testing may be u ed to d term e the q lıty of ıde and aud cha act r t cs f a tel v sı n recei r It may be u ed to meas re the load carry ng chara t rı tıcs f a moto generator set under varying p rating cond tı n *Information* ıs obtained on speed t rque load tempe atur and l ad ffı ıency character s t c

The purp se of s ch testing ı th e fold Fır t ıt ı t e aluate produ t f r formanc t applica ble q l ty stand rd Th s ı referred to as com mer ıal test ng a dı tı g ı hed fr m a c *mplete* eng neerı g test f the product S c nd test g ıs u ed t d sc ver the po sible existence of saf ty haza ds For e ampl le trı al p od ct a e g en *an over* potentı l test to assur a fety t the opera tor under normal ope at ng c nditions Th rd test ıng determ ne the rel ab l ty of the prod ct Relia b l ıty ıs th probab l ty that a p oduct will perform ıts nte ded fun t n under envıronm nt l c nd t ons f to age maintenanc d ope at n Life te ts of the produ t a d te ts t de tru tı are u ed to determ ne relıab lıty For this pu po tests r m de a l m ted numbe of units but the t sts g h y nd omme ı l test g

Stat tı al m th ds re ed xt sı ly l r e l u tıng ı pection nd te t results bec se these methods on ey a tremend s amount of ınf rma tı n r ga dı g ave ge q alıty expected range of v rıatı ı qual ty nd l ab lıty f the product See QUALITY CONTROL [J MN]

B bl graphy W G H lzbock *Inst um nts fo Meas m nt and Co t l* 19 5 C W Ken edy *Insp ct n nd Gaging* 19 1

Instability electrical

A cond t on f unw ted lf-o c ll t n n an am pl fier r t It ı us ally au ed by c st e p t f edba k from utp t t ı p t In a au d o-f eq ncy amplıfi the ın tab l ty may h at l w aud o f equ nc es resulı g n putt putt sounds



Fg 2 Skull and lower jaw of *Ictops* an Ol gocene menotyphlan insect ore (*After W Scott and G Jep se*)

ceous of Mongolia and appear to be primitive relatives of the Leptictidae in which the anterior dentition is aberrant The Endotheriidae (*Endotherium*) occur in the middle Mesozoic of China and may be the most primitive known menotyphlans but they are insufficiently known for meaningful appraisal

Still a third group the Deltatheridioidea most of whose members possess upper teeth bearing only one major cusp or two closely appressed cusps ranging from the Late Cretaceous (Mongolia three genera) to the late Oligocene (North America *Apternodus*) has been placed in the Insectivora in the past but has recently been shown to be more closely related to the Carnivora *See* CARNIVORA FOSSILS

Lipotyphlan insectivores were specialized and gave ri e to no other orders of known mammals The hedgehog supposedly the prime example of a primitive placental mammal since Huxley s day is considerably ad anced over early Cenozoic menotyphlans and all li ing erinaceoid derivatives are even more aberrant The Menotyphla on the other hand gave rise to many orders and may l e regarded as the primitive placental stock some of who e member have survived to modern times to live side by side with lipotyphlan insectivores

[M C MC]

Insectivorous plants

These are plant having variou ly modified highly specialized leave which capture and dige t in ect The proteins of the dige ted in ect bodies supply nitrogen which otherwi e may be unavailal le to the e plants in the places where they grow Sometimes they are al o called carnivorou (fle l eating) plants *See* PITCHER PLANT SUNDEW VENUS FLY TRAP *see also* SARRACENIALES SECRETORY STRUC TURES PLANT

[P D]

Insolation

The amount of solar radiati n which reaches a unit horizontal area of the earth It i tl e latitudinal ariati n of in olation which upplie energy for tl e general circulati n of the atmo phere In ola tion out ide the earth s atmo pl ere dej end n tl e angle of incidence f the s lar l eam and on the solar con tant The lar c n ta t i th amount of energy which in unit time reacl e a unit j lane urface perpendicular to the un rays out i l the earth s atmosphere when the earth is at its mean distance from the sun In olation is mea ured in langleys (ly) or calorie per centimeter quared (ly = cal/cm) A marked winter gradient of insolation exists from clo e to 900 ly/day near the Equator to zero in the dark polar areas but in summer the insolation is quite uniform—over 1000 ly/day near the poles compared with about 800 ly/day near the Equator

The extraterre trial olar energy is modified by the air the clouds and the land and water urface of the earth Energy of wavelengths horter than about 2900 angstroms does not reach the urface but is absorbed high in the atmo phere mainly by nitrogen oxygen and ozone

Air molecules also catter energy in accordance with Rayleigh s law and ab orption by ozone water vapor and other ga es further reduces the olar energy transmitted *See* SCATTERING (ELECTROMAGNETIC RADIATION)

Particles always pre ent in the lower atmo phere scatter and al orb energy too However clouds affect the extraterre trial in olation more than any other atmospheric factor The reflectivity (or al l edo) of clouds varies from le than 10 to o er 90% of the insolation on them The albedo will be higher in visil le light than in total olar energy f r clouds ab orb mainly in the near infrared The cloud albedo depends on the drop ize liquid water content water vapor c ntent and thickne of the cloud it al o depends on the un s zenith di tance Z The maller the drops and the greater the liquid water content other thing l eing the same the greater the cl ud all edo

Cl uds al o al rb olar energy Thick arm (high vapor content) clouds al orb more energy than other cl ud and for cl ud of p ire liquid waterdrop the ab orpti n may reach over 30% of the energy incident on the cloud top

The solar energy measured underneath cloud also depends on the reflectivity of the surface An overca t which tran mit 0 4 of tl e energy incident on it when the cloud i over a f re t will tran mit 0 7 f the incident energy wl en it i locate l over a l ighly refle ting now surfa e Thi i cau d l y the multiple reflecti n l etween the snow an l the cl ud l ut the for t still al rl m re energy than tl e now

All the e atmo pl eri effe t will m lify tl distril uti n of tl olar energy whi h reache tl e ur face For xample H C H ight n c mj ute l th annual al e hown in tl f llowing tal le

Latit di al lation of In lation

Lat i l	0 N	30 N	60 N	90 N (ly/l y)
[illegible]	8 0	10	4 0	3 0
[illegible]	0	0	3 0	0
[illegible]	410	410	00	1 0
[illegible]	0	30	60	1 0

The f cts do not yet ndicate h w di ectlv r in wh t m nn r th g nes may influence de elopment of beha i n any an m l Preformi t po tulate a d ect relat onship between g nes and behavior ep genet c ts p stul te an ind re t r lat onsh p th ough ma y interl ci g f ct s in ganism and dev l pmental tuat n The traditional nat e-nurt re ontro rsy h s wan d instead th em phas s s o the tudy of the r of typical and atyp cal ranges of spe e beha or n evolut on and i ont geny *See* HIBERNATION HOARDI G BE HAVIOR HYPOTHERMIA MIGRATORY BEHAVIOR P YCHOLOGY PHYSIOLOGICAL AND EXPERIMENTAL REPRODUCTIVE BEHAVIOR [T C S]

B bl o phy D O Hebb *Th Organ at on f B h i* 1949 N R F M ie d T C. Schneirla, *Pri pl s f An mal Psychology* 1935

Instrument landing system (ILS)

A fixed beam nt uou wa e low app oa h sys-tem util zing hf lo l ze uhf gl de- lope stat on and e or mo 75 meg cycle marker beac ns Th y tem i also kn wn as nstrument l w ap-p oach ystem (ILAS)

In de t m ke a app oach an a rc aft must fly c ur e th t i n l ned f m ome ele at n t the t hd wn p int on a runway Such a cours n be generat d by the inte ction of two planes One f th e pl ne mu t be vert cal nd sh ld c c de w th the ent r li e of the ru way The e d plane sh ld be app o imately h r zontal l ed f om th de ed elevat n to th t uch d p i t f th ru way The erti al plan s g erated by a g und ad stat on alled a local i e Th l ned pl s p oduced by a parate gr d di tat n kn w a th gl de sl pe sta ti n A th ai raft m es al g th approach ur d tan e t tl tou hd wn p i t i indi cated by the gnals r c ved w th n m ll rea Th gnal a t an mitt d by stat ons called m k be on (se F g 1)

Localizer The lo al zer t n mitte oper te n the 108- t 112 m gacycle b nd It o mally l at d 1000 ft bey d th f r e d of th u w y It feeds a l ne rray on ting f fi e even

F g 1 G ld f m th f d b m l w-app oa h sy t m

F g 2 F ld patt rn f local ze

l iz ntally p lar zed ant nna elements The cen tral el ment (element) in the e antenna arrays i fed with a carr er frequ ncy t gether w th d ba ds of 150 and 90 cycles Th e other el ment are fed with only tl e s deband e ergies resulti g fr m 90- and 150-cycle modul t on The energy feeding the el m nt on one side of the array is 180 out of phase with that f ed ng the oppo ite de of the array In spa e the patterns appear as shown in Fig 2

In the a rcraft a special recei er is u ed to detect the local er ignals It output is con ected to filt r wh ch s pa at the 90- and 150-cycle ignals a d ompa e the r amplitude in a bridg circuit The outp t of th br dge is ppl ed to actuate the vert cal needle f an in trument This needle (see Fig 3) m es right or left depend ng on the rel t e nte ity of the 90- and 150-cycle mod lat on ign ls When th n edle i entered it ind cat th t reception is b ing obtai ed on a cour e d e tly n line w th the ce ter li e of the runway The ens tivity f th ystem is such that f ll c le defle ti of the needl i obta ned when the ai craft is only 2½ off the cent rl ne

A sociated with the ertical c o s poi te instru ment i a sm ll additional pointe marked w th the letters OFF This indicator is ctuated from the um f th 90- nd 150-cy le signals Whene r the 90- r 150- ycle signals o both ha e suffi ie t inte ity th s indic to i retract d to a pos t on wher it is no lo g r s ble S nce th ndic t on of th ert cal n edle i the s me when b th s gn ls re equal or both g al are ab ent the w ning fl g nece s ry t inform the pil t wh th r th nt ed needle ndi at equal ign ls r their ab n

Th e effect f flection from ite may be mini m z d by educ g the beamwidth of th rad ated p tt rn The f e a m dern a tenn d sign em ploy as many 12 elements form ng an a ray w th a l ngth of n a ly 80 ft Th ent e d ecti l l s tha 15 S nce thi p tt n s incapable of fu sh ng gu dan e when n aircraft i off urse mo e than abo i 7 n add t nal rray f d by a econd t an m tte i employed Thi sec nd array

called motorboating or at ultrasonic frequencies that cannot be heard but cause distortion and a drop in efficiency

Instability is a much more serious problem in higher frequency amplifiers particularly micro wave amplifiers because the excessive po itive feedback can be cau ed by the very small capaci tance between two adjacent connecting wires by the capacitance between a component and the metal chassis or even by electron tubes operating at incorrect working voltages *See* AMPLIFIER

[J MR]

Instinctive behavior

Any species typical pattern of responses not clearly habitual or acquired through experience This wording is preferred to the traditional term in stinct which denotes an innate impulse blindly impelling action appropriate to attaining certain end The adjective instinctive is used by ome the Freudians for example to signify certain complex motivated behavior and thus leans toward the clas sical meaning that of an innate drive or predisposi tion to given acts

The problem In every animal species certain characteristic patterns or systems of adaptive ac tion appear under certain conditions Thus many spiders spin webs typical of their species most birds make specie typical ne ts and l eavers build dams and lodges The e activities instinctive in the above sen e po e important questions concern ing their evolutionary basis and genetics their on togeny and psychology and their adaptive signifi cance

Criteria Farlier theorists eeking objective ap proaches to this problem devi ed certain criteria of the in tincti e in behavior particularly appearance shortly after birth or hatching no e ential depend ence upon learning and appearance in the indi id ual rai ed in i olation With further re earch how ever the e criteria all met with ol jection For ex ample the first is contradicted l y evidence that specie typical behavior may appear at stages other than birth the econd by e idence that experience and learning often exert their effects in ways resi t ing clear identification for example eml ryoni stimulati n or prenatal conditioning and the third by the fact that i olation may not exclude extrin ic influence that i stimulati e propertie of tl e in dividual it elf which are characteri tic of the spe cie But the la t two of the e criteria still influ ence many tudent of comparative animal l ehavi r who synonymize with in tinctive such concept as innate nati e and end genous

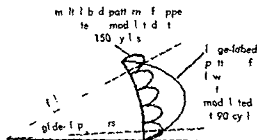
Focal points in research and theory Ol jecti e study demand that the l ehavi r patterns f repr sentative animals l e studied analytically and tl at l a ic a umption l e te ted Research mu t co er environmental condition and *stimuli the range* f behavioral variation and organic conditions un ler lying the development and appearance of th l e havior B tl longitudinal and cr s e ti nal studies of behavioral ontogeny are needed obtained by methods appropriate to the specie and i h genetic controls

In theorizing all conceptual terms mu t be eval uated Thus skeptici m about the in tinct concept centers around traditional dogma which differenti ates psychologically between man conceived a the ole possessor of rea on and lower animal ruled by in tinct This idea is contradicted by much evi dence in comparative p ychology The related a sumption that animals po ess an original innate nature modified only secondarily (if at all) by ex perience is oppo ed by evidence on l ehavi r de velopment The related idea of sharply di tingui h ing instinctive from intelligent behavior is in con trast to evidence that instinctive behavior is often plastic in relation to the ituation Differences in the nature of such behavior and in its develop mental basis doubtless exi t on different phyletic levels

Other un ettled controversial points in re earch and theory concern the role in uch behavi r of (1) neural organization (2) nonnervous organic factors such as hormone and (3) en iti ity and perception together with the relation of the e in ontogeny (development) Some authoritie po tu late the existence of innate central neural coordina tions to account for the ri e and control of in tinc tive behavior others emphasize the role of periph eral mechani ms interwoven with neural proces e in behavioral ontogeny (*see* BEHAVIOR ONTOGENY OF) Clas ical di tinctions l etween reflex and in stinct are que tioned on the gr und that such func tions may differ in degree rather than in kin l The ories distingui hing harply l etween in tinct and learning meet the ol jections that neither of the e i sufficiently well under tood and that l oth may vary greatly in their form and in their relati n hips to development on different phyletic le el

Although all l ehavior is related to heredity the influence of the genes up n l ehavior i a complex que tion still unanswered Gene in the chrom somes mu t exert l a ic influen es on structural growth and through tructure n l ehavior (*see* BEHAVIOR AND HEREDITY GENETIC) Examples of l ehavior d termined r influenced l y structure are readily f und a in liml tructure an l cl arac teri tic gait ellular pigm nt in the retina of the eye and pr neness f r day or night activity size of certain gland such a the adrenal and degree f docility or of wildne H we r it i another mat ter t trace out su l rre p n l nc fr m the f r tiliz l egg tl rough tl e mpl xiti f nt g ny

The geneti s f ome of the p e ie predictal le l el a i ral cl ara teri tic of anin al ha e l en w rked out an l are impr ive Th thr ugl se l tive l reeding of par ntal g n rati n it ha l en po il le to pr du hyl ri l an l l a ker of certain in ect fi he l ir l an l *mammal* diff r ing predi tal ly fr m th par nt in bel avi ral cl ara teri ti u l a l el f xcit r nt parent l behavior and r prod i ti beha i r



Fg 5 M th d f p d g q g l gl d p th by m of t e t g field p tt s d t d f m tw o t s t sp fi d d ff t h ght b e th g d (ILS)

The powe of thes beacons is of th order f 3 atts d th v a c nected t ant nna ystems ns t g of everal in l ne full wa e lements h ch pp the ad at on lo g th ppr ch path nd th by nf t to arr w a ea alo g the path d a w d a at gl t angle to the p th In the a r aft a ep ate y tal nt olled ec r of l w en t tv s util ed pecif ally fo th ec pt n f the m ke beacon gnal Th outp t of th e s onnected to uitable filte wh ch th actuate th ee l ght In me i tall t on a i gl l ght s mployed nd th re f e the g l f om the thr m rk rs are n t pa tely d nt fied Se NAVIGATION SYSTEMS ELECTRONIC PRECISION APPROACH RADAR (PAR)

[P C S]

B bl g phy J S Hall *Rad A ds to Nav ga tion* 1947 P C Sa d tt *El t on Av gat on Eng r g* 1958

Instrument transformer

El t t a fo mer pecifi lly de igned f u e n m a u eme t d nt l uit Th p p e of st m t t n fo m t n e t pr mary lt ge ts t eco dary al s s table for th r lay met r r ther m su g equip. me t A ond pu p to late th h h olt ag p m c t f m the m s ment Th th tr t f mea r ng de c d the pr tect on f p n el s ng su h d i e gr tly mpl fi d by th e f in t m t t ns. f m r A k t h how g tf ba lem t d fl so d agram for n trum nt tr nsf rmer i h n n Fg 1 F gene al d u o f tra f rm TRA SFO R

Spec l d design t hn qu a d m t al e ed n n t um tt f rme t i ur a high de g f t bili t a d l b l ty bec se mpr p op r t n uld e ult n mic l mete i g ppl at r p we y tem d mag r r lay ng ppl at

Th e a tw g al typ f n t um nt tr ns. f m n tr me t p t nt al tr f rm which a ed ltag m a u m t a d i tr ment r t t n f rm wl l ed n r nt m r m nt

Th pr m r f pot t al t an f rm r s n ted th l nd th e t that fl w thr ugh thi winding produces a flux in the core S nce th c re links both the primary and econd ary w ndings a v ltage s induced in the e ondary ci uit The rati of primary to secondary voltag s roughly in pr porti n to the number f t irn in th p ima y and secondary w ndings Usually this rati is sel ted to produce 115 or 1 0 volts at the secondary term nal when rated v ltage is applied t th prima y

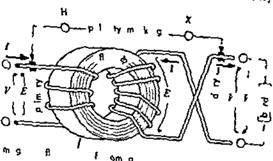
The curr nt tra sform r differs from the poten tial tran former in that the primary winding is de gned for nnection in s rie with the line The ratio of pr m ry t ec ndary current is roughly inver ly proporti n l to the ratio of primary to seconda y turn Usually 5 amp re ec ndary cur rent is p duced by rated urr nt in the primary

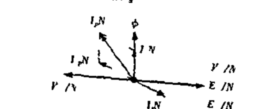
In trument transf rmer may differ considerably since the ph ical c nstruction depends upon the int nded appli ation A potential tran f rmer u u ally has a magnetic core nd c il a rangement th t s quit imilar to that f the con ent nal p wer d t ibution tr nsformer Since the core per ates ontinu usly at the highest flux de ity con s tent with good magnetic d s gn the core is the maj h at prod ce Th er f re hell typ c n t t on u ally is empl yed for effecti e heat dis p t n

In a curre t tr forme the magnet c c re den sity i a fun tion of line current nd except for c s onal t an i nts cau ed by l ne faults is usu lly ery l w The c re los s negligible and the windi gs are the maj ou ce f h t Theref re th o e type of con tru tion s g n rally empl yed

Spe i l n ulati ns u h as arc r si tant b tyl rubber ha e b en de elop d for wind ng n ula t n to en ure nec ry reliability nd afety

Instr ment tra forme s ha e a marked ratio wh h diff r fr m the turn rat and m re nearly





Fg 1 A mpl t m t t fo m d ts ph o p ts d mp d c d op h b m tt d f mpl f t (F m J F K d Appl d El ct J M m t W l y 1956)

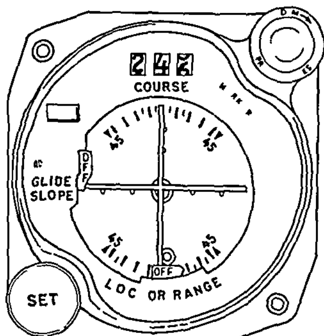


Fig 3 Modern c oss po nter instrument A ma ker beacon l ght is mounted in the upper right hand co ner

employs only three elements and is fed by a trans mitter operating 10 kilocycles from that feeding the main array This transmitter and its a ociated antenna supplies guidance everywhere except in the sector immediately forward When the aircraft is in the forward sector (see Fig 4) its receiver is captured by the more powerful signal from the large array and guidance is furnished by this sig nal with its attendant freedom from site effects *See* ANTENNA (AERIAL)

Glide slope The glide slope equipment operates on a frequency of 329 3 to 335 megacycles This equipment is normally located 450 ft from the ap proach end of the runway and approximately 450 ft from it center line Twenty channels are provided in this band Antenna arrays utilized with the glide slope system are of two general types the equi signal sy tem and the null type system Signals from both sy tems are capable of producing sati factory indications when received by equipments with similar adju tment Both y tem utilize the earth a a reflecting plane

Equisignal system In the e ui ignal sy tem the tran mitter output is modulated with 90 and

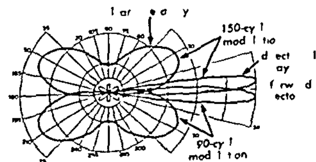


Fig 4 Local ze feld pattern showi g d ct o of p t t rn fo forwa d ecto app oach a d gu da ce fo all other sect

150 cycles The carrier and idebands re ulting from the 90 cycle modulation are fed to a horizontally polarized antenna located at uch a di tance above the ground that only one lobe is formed in the space used This height is approximately 6 ft for glide slope angles of about 2 The carrier and sidebands resulting from the 150 cycle modulati n are connected to an upper antenna located at a height of approximately 28 5 ft This antenna generates five lobes in the ame space as the ingle l be of the 90 cycle signal (see Fig 5)

In the aircraft a special receiver is u ed t receive the glide slope signal At the output of the receiver the 90 and 150 cycle are separated by filters and their intensities compared by a bridge circuit The output of the bridge is connected to a horizontal needle on the in trument previou ly de scrib ed (ee Fig 3) The deflection of the needle upward and downward indicates the vertical po i tion of the aircraft with respect to the optimum approach path As is the practice with the localiz r signals an auxiliary OFF indicator ho that the centering of the needle is actually cau ed by the sufficient inten ity of the 90 and 150-cycle glide lope signals and not by their al ence

Null type system The pattern of the ignal from the lower glide slope antenna i affected by precipi tation To minimize this effect the null type sy tem has been devi ed In this sy tem the upper and lower antennas are fed with carrier and sideband signals re ulting from both the 90- and 150-cycle modulation The upper antenna i located at a height of approximately 33 ft for a de ired vertical angle of approximately 5 and produces two l bes Because of the reflection phenomena the ideband of these two lobes will be in oppo ing pha e The l wer antenna is located at exactly half the height of the upper antenna thu it pr luce a single lobe with a maximum at the same angle for which the upper antenna ha a minimum Deviati n from the glide l pe po ition cau e the 90- or the 150-cycle inten ity to increa e greatly th i cau ing the needle to l fle t either upward r d wnward A deviati n of only ne half degree fr m th e n rmal p ition pro l i e a trong deflection The l er antenna n w l eing at a height of 16 5 ft (rather than 6 ft) i relativ ly unaff te l l y hang in th height of the gr un l plan l re t precipitati n Sn wfall a high a 2 ft pro lu e change in path angl f l than 0 13

Marker beacons T in h t progre al ng th appr oa l path there ar thr marker l a n Th tran mitt r per ting at 5 mega ycles c nf ne th eir ra liati n larg ly t th erti al d m n i n u ing nly mall area f th h riz ntal pl n Th iter m rk r i l at l at a li tan e l appr ximat ly 4 mil from th l n lary f th airf ll an l i m l l te l at fr q n f 400 cy l A mi l ll mark r i l t l ppr imat ly 3 00 ft fr m th appr ch n l f th runway and i m l l t l with a fr q n y f 1300 ycl Th inn r mark r l e t l t th l n lary f th air fiel l i m l ulat l with a fr q f 3000 cy les

m t an el the ppl ed oltage V_p t polar ty s determ ned f r all turns includ ng the econdary

$$E /E = -V_p /V = N_p /N$$

In trument tr nsf m s ha e polarity marks uch th t wh n the c rr t enters the H p imary t t nta u ly lea es th X e ndary and f H h p ti e p tential X s al o p ti e

Clos the ec nd ry circ t of n deal t an forme res lts n a ondary c r ent t with an mmf $\mathfrak{F}$ n the prod c n a magnetizin f ce H

$$\mathfrak{F} = N$$
$$H = N_s i /l$$

he e N i the number of seco d ry tur and l th m gn t cu t length

Thi magn t zin f c must exa tly ancel that of the p m ry s n e n ex t tion fl x is needed f th ideal t an form r

$$N_s /l = -N_p i /l$$
$$i = N \quad N$$

Whe n defined a $-N /N$ the foll wing r l t n n l xs ed

$$i = _p n \qquad E = -E / \qquad V = V /$$

Wh n th co dary r it i l sed the seco d ry current V /Z_b wh Z the sec ndary bu den (the l d a d it wi ing) c mp ed f re t anc R and r a t n e X_b

An ctu l in trum nt t ansformer an be s mu l t d by the two k h n in F g 2a Som am pe e t rn needed to p oduce exc ting fl x i th m gn t c u t A ur e t I thr ugh N turn p od es th fl it has a mag et zi g c mp n nt I d an eddy rr nt and hy t res s watt l s comp e t I Th ar imulated n th equ va lent cu t by acta e X_m and a r istan e R_m r pect ely The t sf m w nd ng l resi t n h w by R d R nd mag ti l akag prod es mall e t n es sh wn by X nd X Eq l t t u t l mt at g th d al transf me b d awn by ef rri g all al es t th ec nd ry a F g 2b o t the pr mary in F g. c

R l f r r f rr g q ant t s fr m the pr mary t th cond ry a (1) mult ply I by ( ) d d I a d E l y nd (3) d d Z_p, R and X by n

Th se q l nt irc ts e ally s t fa t ry to pred t t n f rm pe f rma alth ugh in th t f m th m gn t zat h r t t c i o l n a Cap t i eff ts l ex t Thes h uld be ev l ted at f equen ies bo 100 p d t i u lly nec ty t hang al f X_m d R a f ti n of f qu n y

Accurac es P r t al t f rm r cc a e de pe d n th m gnitud f primary and econdary ltag d ps W th the ndary pe r u ted th lv ltag d p au ed by th xc t g u r t W th a b de it po bl t dd d op d to the b d u t both pr ma y d c d ary t obtain the over all change in performan e I tent al tr nsformers are de igned to ha e low ex c t ng cu rent and l w winding impedances

In a cur ent tr n form r the differ nce between the eco dary and p imary current i the exciting cur ent The ef re small err rs in both ratio and pha ngle ex st fundamentally These errors ary with p nary curr nt and many c mpen ating che nes ha e be n u ed to increa e acci racy B th th magnet zing and ore l s urr nt are k pt sm ll spe ial lam nat n mater al is u ed n l spe cial techniq e are u ed t r d c lo es in the t an former

Comm rcial i st ument tran formers have ex trem ly g od ac ura i at d manuf cturers f rni h typ al curves dep ting an mall err r American Standard f r Transformer Regulat rs and Reac to s (ASA C57) p cifie the accura y cl es for pec fic bu de s and err r a e kept w thin thes tanda d ac ura ies for transf rmers of a gi en cl ss Fo eve gre t r ac ur c es test equipment i a ailable f r accurately mea uring ratios and phase a gl s by e ther d rect method or by comparison w th standa d transformer S e ELECTRICAL MEASUREMENTS [I F K]

Bibl og aphy I F K nn rd *Appl ed El ctr c l M asu em nts* 1956

Instrumental analysis

The u e of an instrum nt to me sure a com pone t to detect the c mpleti of a q ant tati e reacti n or t detect a change in the pr pert s f a syst m

The p e nce f a m asu able chara te ist c h h s unq ely d p de t upo the concent a t on f th sub tan e t l det rm ed i requ red This har cter tic ca be ab orpt or em s n f rgy radi act vity x dat n or red ct n be havi nucl r or lectro ic p op rties magnetic beha o r the mal p op rties The charact risti sh ld be easily m as red and h ld be s mply related t the am u t of mater al nt Ex ampl s of thi appl at a e the d t rmi ati ns f rad um in es by rad oactivity naly of tung t n in t el by m s n spect oscopy f it m A by ult ol t absorpt n n l of coppe i l l gi l mate i ls by pol ography In two c mp nent ystem a p operty of the sy tem a a whole can ften b m a red and related to the d i ed omp ne t. For ample a water ethyl alcoh l mixtu n be analyzed by de ty r r fra t i d x m a rem nts For a ample c ta n g comp nents n − l ep rate me re ment are nec sary

An in t um t an b u ed t dete t the mpl t on of q t tat e r t n when imple meth ds, ch s v sual i d ators, a e not appl able U ually ch ract ri t f the ubst ce be ng d te m ed f the c ent me r d An example th mpe om t c titr t on of ulfate n th lead on whe e th fi t e c s f l d b yo d th e d po t s d tect d b its el ct lyt c r du tio cur nt

represents the true ratio of output to input. However, since the true ratio changes slightly with burden, frequency, temperature changes, and other factors, the marked ratio must be multiplied by a ratio correction factor to give the true ratio under specified operating conditions.

Principles of operation. Instrument transformers approach an ideal transformer, and their principle of operation is explained by a study of the ideal. The practical differences from the ideal can then be incorporated, and equivalent circuits can be established which allow analysis of most instrument transformer problems.

In the ideal instrument transformer the output voltage or current is exactly proportional in magnitude to, and exactly opposite in phase to, the corresponding input voltage or current. This means there is no core or winding loss and no resistance or reactance voltage drops. All the flux links both primary and secondary windings.

An alternating voltage applied to the transformer produces a primary current and a resulting alternating flux ϕ in the core. The same alternating emf e is induced in each primary and secondary turn by the changing flux linkages $d\phi/dt$. For a complete winding the induced voltage equals $-N(d\phi/dt)$, where N is the number of turns.

The instantaneous flux ϕ in an ideal transformer is sinusoidal with a maximum value of ϕ_m when the applied voltage is sinusoidal.

$$\phi = \phi_m \sin \omega t$$

Therefore $$e = -\phi_m N \omega \cos \omega t$$

The root mean square (rms) value of the voltage is

$$E = 4.44 \phi_m N f$$

where f is the frequency. This induced voltage is determined only by the applied voltage and the number of turns, since there are no other voltage drops. Since the induced voltage in the primary E_p

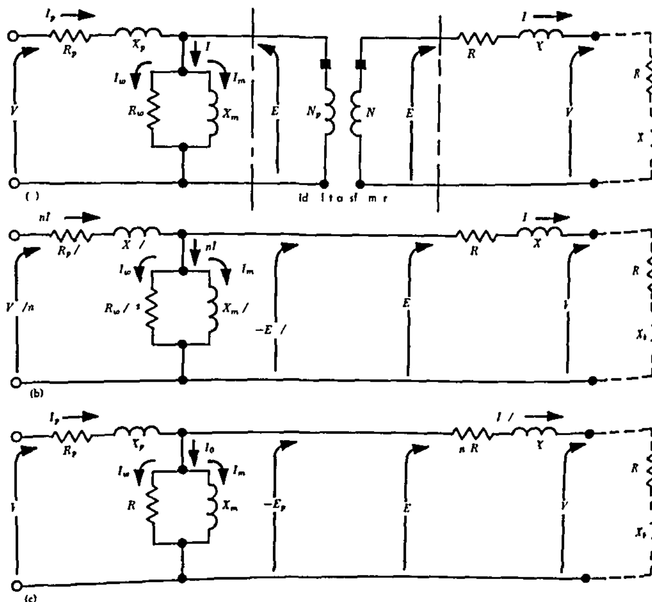


Fig. 2 (a–c) Instrument transformer equivalent circuits. In (b) all quantities are referred to secondary and in (c) they are referred to primary. (From I. F. Kinnard, Applied Electrical Measurements, Wiley, 1956)

ured or cont olled by th in trum nt u h a flow temp ratu p s ure force d spla ement le el tsc ty a cel at n lectri al qu ntit s (volt g curr t, i tan capa itan) or pt cal qu nt t (t a mi io gl colo and bri_ht nes)

An ther method of de gnat g clas ifying in tr m nts p rt c l ly th e f wide applicab l ty s c rd ng t th operat ng p in ipl Ex mple of th m th d ar x ray (mi r copes diffrac tom ter) p ct ometric of var ous typ s fo va us port of th f eq e y p trum or r p ticles (i clud ng i frared lt a l t, vi l l mi o a e x ray y ray n utron le t n and lpha pa t cles) p mati m ch nical elec tr n electri al m gn t c f ydraulic nu lear ac ust c ptic l and pl to_r pl c

E ch of th method f cla ify ng in t ume t u eful nly i pe ific i stan es A i gl i tru ment o n tr m t y tem m y t l e ma y c m b nat ns of d ff r nt p ncipl A g en n tru m nt lt ha m ny appli ati n A y phy i l quant ty m y l meas red by a number of diff r nt prin pl E h of the man perati ns p rfo m d i ha dli g th nform t n fl w i in trum ntat n y tem may b mpl hed by a i ust t h qu a d d i Thu n gl method f la fyi g trume ts po l l and the se r l metl od a sed wher tl y apply

In th e y l pedi me rt cle h din s may b fo d ding to ne f the l fic t ns li ted abo d p nd g on c mm u ag Bec us of th m y rt cle d li g with in trume ts a d me r m nt it mp s ibl to li t r fer t all cl rt l s i thi ncy loped a M st t um nt th t m t phys al q ant t es or p pert o ed i th a t cle d scu s g th t p pert Oth r i str m nt u ed i a p t cul r fi ld m y b f u d by s fu g the art l n th t fi ld Sper fi i trum t m y be th ubject f sepa te a t le if n t th y n be f und by on lt g it d

Scope of instrumentation I trum t t n n l es n to l the d on l nd d al trum t d mp n nt h tal th i teg ati n with a x l a y so ated d vic s i to n t ment y tems (p f m n r m ny f the f ti ns me tio ed bo

In m ny n t um t s t m a x l ry en rgy fi ld s mod fied by the q tit t b me r d a d t a d u d t m s re the m d fi ti n A a e mpl a x y b m pe t tes h t of te l the t ty of th m g t b m depe d a d thu s me u e f th th k f th h t An izat n ham be a ph toc ll tra f rm the ay i i sty t l t i rr t, whi h i f th t f rm d t m i n f the po nt n a met Tl p) l th poi t r i mpa d w th a t d d (th sc l) l h ted n n t of th ckn Va uum pump ay t bes l mp batt el t i gn l g t (oscill t rs) sou d rad o es radioacti e ources, h gh voltage electr n or ion ac celerat r wind tunnel and h ck tube are all examples f equ pment u d t p ovide uch aux iliary fi lds beams or condition

The ge ral phy cal and mathematical princi ples unde ly g the operati n f in truments and in trume t sy tems are d awn fr m all branche f phy i and eng e rin p im ily from phy i In tr m ntation a a c ence is con erned ith th d vel pm nt and tudy of th e e pr nciple and techniq es their applicat t de gn of specific instruments and the ut lization f in trument in r earch eng neer ng test ng indu trial proce e c mmu icati ns defen e educati n and other ar

All i truments ha nhe nt defici ncies The e def c e c es are br adly de crib d by a c racy and pre i i n chara t t c of the n trum t A cu racy i th degre t wh h the me u ed value appr ch th true value P eci on wh ch may be regard d as potential cu a y relate to the c pability f the in trume t to d ti gui h one al of the mea u and fr m other nea ly equal valu when the meas m t a pe f rmed eparately in sp c and time A n trument r p nd in tan t neo sly to hang in the mea rand th lag i dep ndent n the natur l f eq ncy f th in tru ment y t m and its d gree of damping (int rnal di ipati n f en rgy) If th damp ng too g t or th n tur l frequ cy t l w the re p n e l g m y be exc s i e and the i d cation o itp t e i usly i err r d r n an interval f e al t m the nat l per d of the y tem Con e ly if the d mp g i t o mall the dynami re po e may l e e and th utput may exhibit o cillat on befo e attain ng the d red tead y alue In either e nt a d ta l d an lys of th in trume t h ra t n t cs s e ntal t m k appr pr at c rrec t n

M y i trument l ment xhib t drift a low change n p perti w th t me result ng in a chang n utput M y lements al o xh b t th pl om non of h y t esis that i they e hib t a re p t n asing gn l wh h i differe t f m the p nse to dec ea ng gnals En on ment l f ct r s h s t mpe tu e r s br t may also aff ct p rfo mance f ce ta n el m nt Th i t um nt m k r must f o material and op r t g p ipl whi h m n mi th ff ts th u m t develop mea u em nt techniqu wh h e th a o d th e ffi t cor e t for them

I strum nt sy tem a t u n th ph s cal sy tem w th whi h they a e soc at d In m a r m t, the p e nc o p rat n f the ex iting field n g el ment, or m ur n in t um t may unde i ably d tu b ha g the quantity t be mea u ed n automatic o t ol the in trum nt yst m ts p it ely t ha e th beh o f the phy i al y t m

I aut mati nt l y t ms the al e f th var l le t b ontr ll d i comp d with a de ired al f the d ffer ce (r r) gnal ut lized

Instrumental analysis does not require the appearance or disappearance of a characteristic. It can be only an increase or decrease. An example is the pH titration of a weak acid in water where the change in hydronium ion concentration is measured using the change in potential of an electrode in the solution.

Automatic instrumental analysis is applicable to any system. For example, an infrared analyzer can be built into a pipe through which a process stream flows. After the relationship between energy absorption and concentration has been established, the device reports the concentration to the control room and, in addition, makes a record on a graph, all without human supervision. Instruments can also be used to remove a measured quantity of sample, to titrate a given constituent, to clean the titration vessel, and to report the analysis with no help other than the providing of standard reagent solutions and the selection of proper equivalence point conditions. [K.G.S.]

Instrumentation

Designing, manufacturing, and utilizing physical instruments or instrument systems for detection, observation, measurement, automatic control, automatic computation, communication, or data processing. Loosely, the term instrumentation is also used for the ensemble of instruments and auxiliary equipment used in an experiment, test, or process.

Instruments and instrument systems. In the broadest meaning of the word, an instrument is any device useful in accomplishing an objective. Scientific and technical instruments (to be differentiated from surgical, musical, and legal instruments) are devices used in observing, measuring, controlling, recording, computing, or communicating.

Instruments and instrument systems refine, extend, or supplement human faculties and abilities to sense, perceive, communicate, remember, calculate, or reason. The human senses by which we feel, smell, taste, see, hear, maintain balance, estimate distance, and the like are refined or extended by such devices as surface roughness and contour gage, micrometer, chemical analyzer, pH meter, microscope, telescope, gyro-stabilized platform, range finder, and many others. Other instruments such as magnetometers and cosmic ray counters sense or measure physical quantities for which there is no physiological sense developed in human beings. Other instruments (such as cameras, correlators, simulators, and computers) perform functions of storing, transmitting, or processing information signals in ways analogous to or going beyond human abilities to record, remember, communicate, compare, count, and systematically apply logical operation.

The simplest instrument merely provides a material standard with which the user can compare a physical quantity, as in measurement of length by a yardstick. Transducers are instruments which transform the quantity under observation (the measurand) into another quantity for which a standard of comparison is more readily or easily available or which may be transmitted, further transformed, recorded, or otherwise processed for utilization. A liquid-in-glass thermometer transforms temperature (the measurand) into position of the liquid in the stem with an attached scale calibrated in temperature unit.

The signal—a condition, quantity, or magnitude generated by the transducer as representative of the measurand—may be transformed a number of times and in a number of ways in an instrument system. For example, temperature may affect the position of a bimetallic strip whose movement may change the electrical capacitance in a circuit, thereby changing a frequency or voltage which may control the duration of a radiotelemetry signal (pulse duration modulation). The telemetered signal in turn (after transmission, reception, and demodulation) may be transformed into current in a galvanometer which changes the position of a light beam on a photographic film for recording; or it might be transformed by an analog-to-digital converter into a pattern of signals for use in a computer; or the signal might actuate a servomotor or a relay which would adjust the input of heat into the region of the bimetallic strip to control temperature.

Each of the many transformation of a signal throughout an instrument system may result in some additional lag and often in a loss in accuracy, but may be justified by convenience or necessity and even by improved over-all system accuracy or response characteristic.

The following list includes some of the more important functions of instruments or components of instrumentation systems in creating or handling signals (or information or data): excitation, generation, modulation, detection, comparison, amplification, differentiation, integration, attenuation, conversion, switching, counting, coding, timing, programming, correlating, linearizing, correcting, displaying, recording, reducing, analyzing, computing, and controlling. Since all branches of experimental science and technology depend on instrumentation, specialized instrument with a corresponding body of knowledge and practice has been developed separately in many fields. Thus chemical instrumentation, aeronautical instrumentation, medical instrumentation, optical instrumentation, and many other similar terms indicate areas of specialization in various industries or professions.

Instruments are sometimes classified according to the field of purpose or application, as chemical, navigation instruments, surveying instruments, or oceanographic instruments; according to their functions in instrument systems, such as instruments for measurement, recording, computing, controlling, signal modification, or display; or according to the physical quantity or property that is to be meas-

fo example th explo tion of space gene ation f power by nucl ar eacto s and determination f high temper t re p perties of mat rial presents new in trument ti n pr blems In general in strumentat on resea ch eeks t atta n highet accu ac e greate ns ti tie capability of mea uring xtreme alue applicability under tr m cond ti of u and c p bility of re l ng changes o eff cts that occur at extremely high peeds, su h as nucl ar ph nomen S e PHYSICAL MEASUREMENT

The tre d to wider use of in trumentation for a t m ti m asu ement and ntr l n industry s c ntinually ac le at ng and whol n w ndu trie a e eme gi g wh ch uld t xi t without highly soph ticated n trument ti n Th s trend will on tinu at a rat l mit d only by question of co t fety and reliab l ty Reliab l ty part ci larly of electr c compo e t h been r us problem but w ll imp o e as a es lt f devel pm nts in solid t te c cu t lement new mate als new techniqu a d m r att nti n t e all syst m e gine ng S RE IABILITY OF EQUIPMENT

An ther gn fi ant t end i th increa ng ut l zati of dat pr ce g devic s r o der c m p te s and sim la qu pme t for automati rting sto ge and p d elect etrie al of i formati n and nume ical data in b nk ng a counting and doc ment t on S milar de es r be ng adapted fo autom t e d g, l ad ng t aut matic lan guage t an lation

Compute theory s b ing extended t the de ign of log e m h nes and elf-organ ing ystem whi h may imul t not nly th pr ces es f r m mbering a d e on ng but al o the p oces f lea ning M re e ten on f speed and cap ity w ll soon make f as ble th u f ompute t com p te w th r predict on f m analys s f meteoro l gic l d ta f om a wo ld w de ob erv t n n t w k t an lyze a d f ecat n m tre ds to a se s l g ti r qui m nts and m l tary c pab l t a d to p ed t th pr b ble ut ome f mil t ry t es or pol t cal c nt ts.

In the med l fi ld trument t on f r a to m ti te t ng f phys ol gi l bioch mi al d n rolog cal pa m te now ba ly me gi g b t ert n to b om w d p ead Correlati n dev c re b g devel ped f d agn t and l n l n t m t fo locati n a d ident fication f m m l ll r m lt plyi g in numb r d p ci n

In educati a di i u l in t m nts re bei g dev l ped int s vely Supplem t d by a tomat c ti g dev es nd other trum nt for le ning th p m gr ti re es the ffi ency f the hole educ i n l y t m [W A W]

B bliog aphy W G B l (ed) *Phy c l M th od Ch mi al A aly is* ol l 1950 H Ch st t, d R W M y *S m cha i ms d Reg l i g Syst m D g* 19 l D M Con d ne *ied P s l t m nt d Cont ol of H db ok* 19 B C D lahook *I d tri l C t l I st u m nt* 1956 C S D per W M ka a d S Lee *Instrument F gineering* 3 ols 195? D P Eck man *Indu trial Instrumentation* 1950 E M Grabbe *Automation in Business and Industry* 1957 E M Grabbe et al (eds) *Handbook of Automation Computation and Control* 3 ols 1958 I A G eenwood J V H ldam and D Mac Rae *Electronic Instruments* vol 21 1948 F K Ha ri *El ctrical Measurements* 195? I F Kin n rd *Applied Flectrical Measu ements* 1956 Arthur D Little Inc *Electronic Data Processing Indust y* 1956 G J Murphy *Basic Automatic Cont ol Th ory* 19 7 M H Nichols, and L L Rau h *R di Telemetry* 2d ed 1956 H C Rob rt *M chanical Meas rem nt by Electrical Meth od* 2d ed 1951 T N Whiteh ad *The Design and Use of Instruments and Accurate Mech nism* 19 4

Insulation electric

Mat rial of h gh resi t ity u ed t confine the elec trons in a cond ct r o t may gu de them to s me u ful de ce. For electric wiri g the ins lation is l m ted t fairly flexible types

INSULATION REQUIREMENTS

Th applic t on f insulations ar o varied that ch ice must b made aft r con deration of the nece a y pr pert es and the w ak es es of the in sul t on, nd f th pe ial circum tances of in tallatio No in ul tio ha all the ad ant ges the nsulati n sh ld be so ho n that ts dis d a tages a e not a d t iment in the spec fic applica t on

M y de rable characteri t cs are n t perma nt. Th ref re the p opert es of th materi l after a per od of ye rs n the en r nmental onditi ns must als be known New mate als requi e time t devel p their unf reseen weaknes es

Electrical requirements These vary with u e pecific p op rtie of te est depend upon the ap plica n The import nt properties of insul ti n are d cu sed b iefl *Se* DIELECTRICS

Re ist ty Comm nly m a ur d as n ulati n e s ta th s is ba ed on a dir ct-current m a ure ment of fl w into the in ulat n afte el ct ifi a ti n of l m n The curr nt b uld b mall nd the i ul t n e i tan e large In t elf it i not per hap th mo t imp rtant ch ra te i tic but d te o rat on i olt n f und to oc ur fa te in low in ula t on r s ta ce m terials und r weathering condi ti s It is a *aluabl* mea of c nsi tency and un f rm ty in m nufa *re If* in service it hould d p bruptly r f ly r p dly ervic fa lu is l k ly to f ll w

D el ct c st ngth Th pr perty d termines the b l ty of th s lat n t re i t pun tu by elec tric pot ntial It is ad ely aff t d by we ther i g o aging b h gh temp rature by tin ed heat and by the ent ance of mo tu

Pow fa to Th s is a me sure f the p we lo n the l t n and hould be l w A rap d n ea i a da g r gn It i import nt in h gh ltag cables but n important in low olt ge c bl e ept thos u ed for mmun tion It

to initiate corrective action Since the output measurement i u ed t control the input su h y tem are called clo e l loop or feedback control y tems For di cu ion of the u e of in trumentation in control y tems see CONTROL SYSTEMS SERVOMECHANI M

If the re pon e characteri tics of the in trument sy tem are not appropriately matched to tho e of the controlle l sy tem the parameter of the com bined y tem may exhibit tran ient or u tained o cillation The general problem in de ign or analy i of automatic control sy tems is to deter mine and obtain the in trument performance which will en ure the optimum speed of re pon e con i t ent with tability For linear sy tems (tho e for which output re p n e is proportional to input) this may be done analytically Text on instrument engineering ervomechanism or mechanics de cribe the everal mathematical procedures com monly u ed for analy is of imple in trument mea uring y tems and control y tem For non linear y tem digital computers may provide o lution of acceptable accuracy

Analog computers or imulator provide rapid nonanalytic solution for behavior of linear (or to ome extent nonlinear) sy tems under various con ditions Both types of computer are not only u ed to tu ly y tem but are increa ingly include l a part of y tem who e behavi r they predict and control Digital computers al o find major u es in rapid torage retrieval and proce ing of data of all type and for ol ing cientific problem of great complexity See COMPUTER

The entire field of military technology re ts largely up n modern devel pment in in trumenta tion many of which in fact re ulted from military need Radar onar and infrared detector are u ed n t only for detection but al o in combination with computer and c ntrol y tem for automatic guidance of weapon Homing torpedoe elf guided mi il and computer controlled antimi sile mi ile are examples of the radical hang in method of warfare re ulting fr m in trum ntati n whereby warhea ls are aut matically guided t rather than merely thrown at the nemy

In trumentati n f r mea urement of nuclear ra diation i the ba i for all military and peaceful u e of at mic energy and radioactive i ot p

Thus the c pe of in trumentati n i n arly uni ver al it may well be called a common denomina tor of all of science and t hnology

Related fields Becau of th univer al scope of in trumentation there are many fiel l that are clo ely relate l

Systems engineering Thi term i applied t th de ign or analy i of proce or machine sy t m a well a in trum nt sy t m In trumentati n y tems primarily in olve the fl w of signal (inf r mation) wherea the physical system or proc involve primarily the flow of en rgy material or both Since the same general law apply t all phy ical system and since in tr ment are crit ally in neering i a large and neces ary part of sy tems engineering in any fiel l uch as aircraft mi les oil refining teel rolling and communicati ns See SYSTEMS ENGINEERING

A fundamental part of in trument y tem engi neering relates t the theory of automatic control and to the practical application of automatic con trol equipment

Information theory Thi body of mathematical and logical knowledge developed for analy i of the efficiency and the limitation of communication sy tems is broadly applicable to all types of sig nals or data and is thus important to in trumenta tion In any in trument or y tem the output signal varies to ome extent in an unpredictable manner becau e of di turbing influence some of wh h may be inherent in the in trument or y tem The unde ired ignal is often referred t as noi e The ratio of the magnitude of the ignal to that of the noi e is important as an indicati n of po ible error limits and detectability limit The frequency range of ignals that can be utilized by an in trument y tem determine the amount of useful m a ure ment data that can be handled per unit of time The fundamental definitions of inf rmati n fr quency bandwidth noi e channel capacity and their interrelations are all invol ed in inf rmation theory thu thi field i clearly of ba ic impor tance to in trumentation and particularly t c m munication in truments and y tem See INFORMA TION THEORY

Human engineering This is frequently inv l ed in in trumentation To be operated by or to pro ide informati n to an ob erver in trumentati n sy tem should be de igned to take account of hi ph ical phy iological and p ychological characteri ti In de ign of dial di play or manipulative element vi ual acuity and body characteri tic mu t be c n si lered in analy i or de ign of y tem in wh h a human being provi le a link bet een mea re ment and c ntrol the reacti n time and deci i n capabilitie of th human being and hi s cepti bility to fatigue and to envir nmental factors mu t al o be taken into account See HUMAN ENGINEER ING

Cybernetics Cyb rn tic relate t the fiel of man machine communication and the applicati n of inf rmati n th ory to re pon and aut mat contr l in phy i l gical sy tem It i thu an th r fi ld which partl inclu l and i partly included in the fiel l of in trumentati n See CYBERNETICS

Automati n Thi recentl intr d i ed t rm still ha variou meaning but g n rally impli th ap plicati n of a it matic contr l to an operat n or proces A a t rm applied t econ mi and tech n l g al tr n l it impli the mod rnizati n f in l i trial op rati n to utiliz m hanized eq ip m nt and in trum nt f r a it m ti contr l mea urem nt and data h n lling t a gre t r degree S AUTOMATION

Trends in instrumentation A l an in en and technol gy m k r i re ing l m n l n

f r *example* the expl rat of space ge erati n of power by nuclea react r and det rmination f high temperature propertie of mate ials pre se t new in trumentat on probl ms In general n strumentation res ar h eeks to attain higher accu raci s, greater en ti t es capability of measuring xtreme values appli abil ty u d r extreme condi ti n of use and capab l ty of resol ing changes or eff cts that ccur at extremely h gh pe ds s h as nucl a phenom na *See* PHYSICAL MEASUREMENT

The tre d t wider u e of nstrumentation fo tom tic mea rem nt and ntrol i dustry is co tinually accel rating and whole new ndustri s a e eme ging wh ch c uld n t ex st w thout highly soph t c ted in trum ntati n This trend will con t u at a rate l m ted only by qu t ons of c t saf ty and rel bility Reli bility parti larly of ele t o c c mpo ent ha b n a seri us problem but w ll mprove a a result f d elopments in solid t t e cu t el me t n w mat ials new tech qu s and mo e atte t on to o er all system eng n r ng S RELIABILITY OF EQUIPMENT

An ti g ificant trend is th nc a ing ut li zat n of data proce ing devi s, r corde s om p t s and m lar eq ipment for aut m t c orting sto g and r p d sele ti e retr e al of inform t on d nume al d ta i bank g a counting d doc m ntat on S mila d c s are be ng ad pt d fo utomat c read g l d ng to automat c lan gu ge tran l t on

Comput r theo y s bei g xtended t the de gn of l g c ma h n s nd elf-o ga ing y tems whi h may sim late not only the pr ce s of re memb ng and rea o ng b t l the pr cess of lea n g Me xt n on of speed and cap c ty will oon mak fe bl th u f c mp te s to om pute weathe p edicti n from analy is of met o o l gi l data f om a w ld w de bs rvat o n t w rk t analyze and fcre a t co m c t end t se l g t r q ir m nts and m l t ry capab l t s nd t pred t th pr bable utcome of mil t ry nt r r politi al c t ts

In the m di al fi ld tr m ntat on fo automat t t g of phy i log cal b l mical and e l g al pa met rs now b ly me g ng but s rtain t bec me widespr ad Correlatio d ices a e b g dev l ped f r d agn s and cl n i l i strume ts f locati n a d id ntifi at on of nternal ll r mult ply ng n number and p ec)

In ed ati a d o is l in trum nt a e being d eloped nt n i ly S ppl m nted by automatic ac r ng dev es and oth t uments f r learn ng th y pr m great a th effic ncy f the h l edu at n l y t m [W A W]

B bl g phy W G B l (ed) *Phy l M th d n Ch m I 4 ly* l l 1950 H Ch t n t a d R W May *S rv me h t m d Regu l g Sy t m D gn* 19 l D M Co id ne (ed) *P l t m nt a d C t ls H dbo k* 19 B C D lahooke *I d st ial C t l I st m t* 1956 C S D pe W McK y a d S Lees *Instrument Engineering* 3 ols 1952 D P Eckman *Industrial Instrum ntat on* 1950 E M Grabbe *Automation in Business and Industry* 1957 E M Grabbe et al (eds) *Ha dbook of Automatio Computation and C ntrol* 3 vols 1958 I A Greenwood J V Holdam and D MacRae *El ct onic Instruments* ol 21 1948 F K Harris *Electri al Measureme ts* 1952 I F Kinnard *Applied Electrical Mea urements* 1956 Arthur D Little Inc *Elect oni Data Processi g Industry* 1956 G J Murphy *Basic Automatic Control Theory* 19 7 M H Nichols and L L Rauch *Rad o Telemetry* 2d ed 1956 H C Robert *Mech n cal Meas rements by Electrical Methods* 2d d 1951 T N Whitehead *The Design and Use of Instruments and Accurate Mechanism* 19 4

Insulation electric

Mat l of h gh re isti ty u ed to confine the elec tron in a conduct r o it may g ide them to some u eful dev e Fo lect ic wiring the insulati n is limited to fa rly flexible types

INSULATION REQUIREMENTS

The appl cation f insulat ons are o a ied that cho ce mu t be m de fter c n id r tion of the nece sary prope t e and the weaknes es of the in sulation and f th pec al c r um tance of in tall t on No in ul ti n has all the ad ant ge the i sulat n sho ld be o ch en that its d d an tag a e not a det iment i the specific appl ca tion

Many desi able haracteri tics are not perma nent. The efore the prope ties f the m *terial alter* a p riod of ye rs n the en iro mental condition m st al b kn wn New m te i l r q ire t me t *de el p th r u fo e een weakn s es*

Electrical requirements These vary with use sp ific prop rti s f interest depe d upon the p pl at o The importa t p pert es of nsul tion are di u sed br efly *See* DIELECTRICS

R st ity Commonly mea u ed as n ul ti n re s tanc th s i ba ed on a di ct cur nt measu e ment f fl w into the in ulati n afte el ctrifi a t on of l m n The urrent hould l e small and the in lat n e st nce larg In itself it i not per h ps th mo t imp tant char ct rist c but determ r ti n s fi n f u d t occu f ter in low n la t on r sta e materials und r weathering co di ti ns It is a lu ble measure f con i tency and uniform ty i manufactur If in rvice it should d op bruptly or fairly apidly a ervic f lure s l kely t f ll w

D el ctri st ngth Th s prop rty d term nes the ab l ty of the in ulatio to r si t pun tu e by elec t c potent als It ad er ly aff cted by weath r i g or gi g by high temper re by c nt nu d heat and by th ent anc of m i tu

Pow f to Th s i mea ur of the p wer l s t the insulat on and hould be *l w A* ap d n *c* e s a dang sign It i mport nt in h gh voltag ble b t imj t t i low oltage ca ble xc pt th s used *for* c mmunicat n It

to initiate corrective action Since the output measurement is used to control the input such systems are called closed loop or feedback control systems For discussion of the use of instrumentation in control systems *see* CONTROL SYSTEMS SERVOMECHANISM

If the response characteristics of the instrument system are not appropriately matched to those of the controlled system the parameters of the combined systems may exhibit transient or sustained oscillations The general problem in design or analysis of automatic control systems is to determine and obtain the instrument performance which will ensure the optimum speed of response consistent with stability For linear systems (those for which output response is proportional to input) this may be done analytically Texts on instrument engineering servomechanisms or mechanics describe the several mathematical procedures commonly used for analysis of simple instruments measuring systems and control systems For nonlinear systems digital computers may provide solutions of acceptable accuracy

Analog computers or simulators provide rapid nonanalytic solutions for behavior of linear (or to some extent nonlinear) systems under various conditions Both types of computer are not only used to study systems but are increasingly included as part of systems whose behavior they predict and control Digital computers also find major uses in rapid storage retrieval and processing of data of all types and for solving scientific problems of great complexity *See* COMPUTER

The entire field of military technology rests largely upon modern developments in instrumentation many of which in fact resulted from military needs Radar sonar and infrared detectors are used not only for detection but also in combination with computers and control systems for automatic guidance of weapons Homing torpedoes self guided missiles and computer controlled antimissile missiles are examples of the radical change in methods of warfare resulting from instrumentation whereby warheads are automatically guided to rather than merely thrown at the enemy

Instrumentation for measurement of nuclear radiation is the basis for all military and peaceful uses of atomic energy and radioactive isotopes

Thus the scope of instrumentation is nearly universal it may well be called a common denominator of all of science and technology

Related fields Because of the universal scope of instrumentation there are many fields that are closely related

Systems engineering This term is applied to the design or analysis of process or machine systems as well as instrument systems Instrumentation systems primarily involve the flow of signals (information) whereas the physical *system or process* involves primarily the flow of energy material or both Since the same general laws apply to all physical systems and since instruments are critically involved in most systems instrument systems engineering is a large and necessary part of system engineering in any field such as aircraft missiles oil refining steel rolling and communications *See* SYSTEMS ENGINEERING

A fundamental part of instrument systems engineering relates to the theory of automatic control and to the practical application of automatic control equipment

Information theory This body of mathematical and logical knowledge developed for analysis of the efficiency and the limitations of communication systems is broadly applicable to all types of signals or data and is thus important to instrumentation In any instrument or system the output signal varies to some extent in an unpredictable manner because of disturbing influences some of which may be inherent in the instrument or system The undesired signal is often referred to as noise The ratio of the magnitude of the signal to that of the noise is important as an indication of possible error limits and detectability limits The frequency range of signals that can be utilized by an instrument system determines the amount of useful measurement data that can be handled per unit of time The fundamental definitions of information frequency bandwidth noise channel capacity and their interrelations are all involved in information theory thus this field is clearly of basic importance to instrumentation and particularly to communication instruments and systems *See* INFORMATION THEORY

Human engineering This is frequently involved in instrumentation To be operated by or to provide information to an observer instrumentation systems should be designed to take account of his physical physiological and psychological characteristics In design of dials displays or manipulative element visual acuity and body characteristics must be considered in analysis or design of systems in which a human being provides a link between measurement and control the reaction times and decision capabilities of the human being and his susceptibility to fatigue and to environmental factors must also be taken into account *See* HUMAN ENGINEERING

Cybernetics Cybernetics relates to the field of man machine communications and the application of information theory to response and automatic control in physiological systems It is thus another field which partly includes and is partly included in the field of instrumentation *See* CYBERNETICS

Automation This recently introduced term still has various meanings but generally implies the application of automatic controls to an operation or process As a term applied to economic and technological trend it implies the modernization of industrial operations to utilize mechanized equipment and instruments for automatic control measurement *and data handling to a greater degree* *See* AUTOMATION

Trends in instrumentation Advances in science and technology make ever increasing demands on instrumentation Every new ... of investigation

Som ch ract i tics of pl sti i s latio

Ch ra teri t c	P ly thyl ne	P ly tyren	Poly nyl hl rid	M;l	Nylo	Tefl n	hel F
In ul t es ta ce	H gh	H gh	Can be anyt!	Good	F ir	Good	Good
D lectri t e gth	Good	Good	Can be anything	Good	I	Good	Good
P w f ct	Low	Low	R the high	Low	H gh	Low	Low
D lectri consta t	Low	Low	M d um	Low	Medi m	Medi m	Medium
Chem cal es ta ce	Good	Good	Good to f	Good	Good to fa r	Good	Good
W t r pe meab l ty	Good	Good	Good to f r	Good	Fa r	Good	Good
Re ta ce to nlight	Good if bl k	F ir	Can be good	Fa r to good	Good if bl k	Good	Good
Flamm ble	Yes	Yes	No	Yes	Yes	N	N
Ten l t gth	Good	Good	Good	H gh	Good	Good	Good
Resista ce to d f rm tio	Fair	Good	F	Good	Good	Good	Good
Abra esista e	Good	F to good	Good	Good	Good	Good	Good
St ff ess	Cons d bl	Extreme	Anything des red		Con d bl	Con ide abl	Con d ble
Cost	Low	Low	Low	R th r h gh	Fa	H gh	H gh

P ly yl hlo d Th s pla t c n w d u today It i d ffi lt t g ral it p operti e and t a b m; ded t mak a ngle pr pe ty x pt al The table h uld be i terp eted with th t l m t t in m d ft d st n tly n it t t mp t r lt n g f te tha y ly thyl e up t a point d b m ng h d r t low tempe t es It al bject to flow u d pres ur ev n t om t mp tu

Myl Th s ot n mu h use as an i ul ti n lth ugh t can be ed n th n t p f rm S e POLY ST R RESINS

Nyl n S m la t myla in m ny way nyl n is ut t d ng i ab a re t n but s n t u ed s abl ulati It u lly sed f r its phy i cal ben fit r th th n a an nsul to Se POLY

UOE RE t

T fl nd K l F These hl r e-fluor e om p u d h l m t d appl t n Th y a norm lly t ff d so m t be u d n thi la s Th y w th t d h gh temp atu (e 200 C) th n any th m fl x ble I t n S POLYFLUO OOLE FIN RE IN

Thermosetting materials M t als n th s l r n mally ft They can b t ded d r p s d th h at t ted u t l th longe)ft h ool

Rubb mp d F l t n rubbe c m po nd a e h nged f om pl t c f rm t el t d t n l mb ti with lf r Th he t tr atm nt i lled f min g Nat al r bbe used l f q ntly f r in l t r recent y a a th r m t l h bec m a lal l

Sy th ub (Bu a S) M m de a d a e f lly o tr lled y thet c ubb r la k the f gn m tt f r l bbe nd t m u f rm Flect l i l t n a be m de w th ithe n t ral or syntheti rubbe but the latter hould yield mo n form a d repr d c bl res lts

Rubbe comp u d can be m d w th good n s lat n r ista nd d elect i tr gth m d m pow r fa to nd S I C and w th res tance to chem c ls w athe ng, and mo t co d ti ns They a e mo fl xibl and are easi r to ha dle and in tall th n pla t c

Us ally they need p ot t n fr m mechan al ab s They bur a d ar u lly l m ted t a maxi m m ir t oltag f 35 000 lt The g g f su h c mp und usuall au es them to harden but il u d st rbed th y nti ue to functio el c t c ll

Butyl Thi synth t rubb ha not be n u d t the h ghest oltages beca e it dielectric trength i l ss than th t f B n S and f natural ubbe It w ll n t ha d n u der us in tead it oftens Ag n c rt i ch racteri ti s re a entu ted n some omp d r d not n ther o g n al zat n f haracte t s ca n t ccu at ly every c

Neop n Th s bb l k mat l p ded t lo k) k a bbe mp und It does n t ha e th ele t ical p pe t usu lly equ ed a d ed princ p lly f tl e m h n al p te t f s lat n wh h t e l es S h neop n sh ths h fine t n le tr ngth h a o nd c sh ng i ta They e t th ff t of th su d o l H w v r l nd w t r c n p trate th m

Sil c ubbe Th s a e pen e m t rial b t t t d ged by temp at e f m 150 t 00 C It l t c l p p rt a good It u ally phy ic lly we k, alth gh thi n b m pro ed m v et s S RUBBER SILICONE RESI S

usually increases with rise in temperature of the insulation

Dielectric constant Also known as S I C (specific inductive capacity) this is a measure of the charge required to bring the apparatus up to voltage compared to that required if air were substituted for the insulation It is principally of importance in communication circuits and low values are preferred except for capacitors where high dielectric constants provide high energy storage in a small volume See DIELECTRIC CONSTANT

Temperature requirements These vary with each application and installation A compromise is usually necessary because an insulation good for high temperatures has other shortcomings and the same for low temperatures The Electrical Code and American Institute of Electrical Engineers Standards give limiting temperatures at which specific insulations shall be u ed This means the final temperature of the insulation which is the result of the temperature of the surrounding medium usually air and the heat from the current in the cable conductor Temperature should be maintained at a value at which the insulation will last for a long time Most insulations are stiffer and more likely to crack on bending at lower temperatures and conversely to soften at higher temperatures This applies to temperatures applied for short duration Higher temperatures applied for long duration usually harden and possibly embrittle insulation although some new rubber compounds soften and become puttylike In both cases the value of the insulation is impaired and electrical failure may occur if bent in the first case or due to its own weight in the latter case

Where a nonflammable cable is required some other desirable property must usually be sacrificed

Mechanical requirements Normally electric insulation should be designed to hold electricity not to withstand mechanical abuse For the necessary rough treatment that may occur in installation of cable braids tapes or sheaths are employed over the insulation as a protection These can be designed to withstand the mechanical treatment likely to occur and the insulation can be designed for optimum electrical functions Of course the insulation should not break at the low temperatures anticipated or soften at the high ones Some materials will even flow at temperatures not usually considered high these are unreliable as insulation

Chemical requirements These are usually determined by the specific application intended for the wire Sometimes resi tance to oil or liquids gas fume or airborne powders in chemical plants is required It is usually the mechanical protection of the insulation that must be designed to withstand this environment rather than the insulati n and each case need *special consideration*

Chemicals in the soil around buried cables or in ducts and manholes around duct cables can cause *deterioration* This again usually occurs on the mechanical protection of the cable but may apply to the insulation itself About the only guide for choice is to use an insulation that has proven by many years of service its suitability for uch conditions

Water can have disastrous effects if it enters the insulating medium of a cable This is e pecially true with paper insulation either dry or oiled or with varnished cambric Some compounds of rubber can hold appreciable amounts of water without harm to their electrical properties but others are seriously affected In many cases water absorption as a criterion of serviceability of an in u lation is exaggerated and undue importance may be given to it Its importance actually depends on its effect on the life or the electrical properties needed for the specific application of the in ulating material

Many seemingly impervious materials have been used for keeping water and oil or hydrocarbons away from insulation with the later disco ery that these liquids can pass through the barrier without adversely affecting it It is thought electric potentials sometimes aid in the transfer and penetration by the liquid

FLEXIBLE INSULATION

Insulating materials are often only one ingredient in a compound finally applied to a wire as insulation An infinite variety of mixtures can re ult all based on the same primary ingredient whicl often gives its name to the cla s Still the properties of the compounds may be so different as not to de erve grouping as a certain cla Such compounding may make a poor material or an out tand ing one both with the same major ingredient In general insulations are either thermopla tic or thermosetting In others the effect of heat has no function There are many insulating material only the more important are discussed here

Thermoplastic insulation Materials in this cla s can be softened by heating o they can be extr ided and when cool return to their original conditi n The general characteristics of the e material are compared in the table

Polyethylene This is particularly important for high frequency applications however it ha short comings It melts at about 110 C so that sl ort circuits or o erloads of current on a cable may cau e the insulation to run off It is very stiff and in thick walls on wire may pr e too stiff for u eful ness Cases of cracking have occurred in ervice mo tl due to certain g ea es or hydrocarbon Newer higher molecular weight p lyethylene is designed to avoid this but may lo e ome of tl e ad vantage f the original polyetl yle e See POLYOLFFIN RESINS

Polystyrene This al o ha ex eptional electrical propertie but it must be u ed in thin film or where it will not be l ent l e a se thick walls are tiff and l rittle Its electrical properties are le s affected by change of temperature than most in sulat ons See POLYVINYL RESINS

ith tand b nd ng durmg ma factu e but nly ba t th t nd low oltage It i u ually appl ed i th f rm f enam l or cott n e i g but f r larg machines th trand m y be wrapped witl glas fber l est r m ca pap r tap r with paper in th e e of il filled t ansformer The turn in ulation i form d by wrappi g the conduc to s w th tape or by nterp ing pa ato s of he t mate i l The n ulat on to gr d m y be f rm d of r g d p ols o wh ch th coils are wou d fo mall tr n f rm s and fi ld l or m y e n t f lot l ners made of Myl r r II l e a etate film pap r m ca r gl cl th r a comb n t n f th e in mall r tatin machines For l rge r t ting ma hin th ils r wr pped w th fl x bl h et t p d e tho oughly im p egn ted w th in l t g arn h The c ls may b molded the i a press or by mm r n i a l q d u der he t d pre sure The n ulati n is appl ed in erl pping l y rs d pp d i arn h nd b ked t make th u fa e c eep ge paths l ng a d t seal the i t r ti es

R g d n l t n sy t m ha an alm t nfi t riety f p bl f rm dep ndi g o the siz typ i te d d e a d e i o m nt of the equ p- m nt Any o pec f pp atus m y e a ty f m t rials i many d ffi nt fo m a om pon nt f it s l ti n y t m After ele t n tl m t table nd ompat ble mate al the de gne mu t pro d f r th appl cat n nd as- embly s h w ys th t the mpl t d t uct e w ll ha e ad quate d le t i tr gth both i t ally nd n a l g t me ba nd w ll w th ta d ll th overs lt g m han l t e e temp a tu e a d r m ntal e p u s th t m y o ur in s n c

Voltage requirements U ally cl d on d t r r gid in l t n y te r eq i ed to w thst nd i ti lly a te t oltag f tw ce the up ply olt ge pl 1000 lt Add t nal t t ch a r peated g impul lt g s may be e- qi red t heck the tr nd and t rn i ul t n A h f p bl m i m et ng th e r qi r m nt s t th t th ltag d tr b ti al ng the w nd ng d o s h th kn s f nsul t o does t e t essa y p rt

A i d ted th f g r th d l ctr c t e al ng a y path made p f d ffi ent mate i l n se es i n ersely pr p rt al t th r al e of th d l t n t nt K K i lly 3–6 f r grd n ul t nd l f a r so that a th n laye f ai betw the i ulati n and a al t w ll may h ve t s th ee mo e tim th t n the insul t n itself Beca a bre k d wn at b t 80 lt / mil lect d h rg o c r a may be xp ted h e th l t n st e e eeds about 30 lt m l ales preve t e tep re t k The e- f th l t port n f h gh olt g l e g n m du t g ating which h t r t th e t m l pa nd r al m de f o es t tmat al ch a m e

Temperature requirements Org n in l t ng m t al u d g h m l and phy i l ch nges when expo ed to high temperature The rates of m t ch m c l reactions such as oxidation of cellu lo e d ubl and th refore the seft l l fe of mo t in ulatio systems is rou hly hal ed f r each 10 C increa e in temperatu e Insulating materials are grouped in tempe ature Cla e O A B F and H w th ominal contin ou temperature lim t of 90 105 130 155 and 180 C, e pect vely Varni h treated c tton pape e amel and mo t org n c mater als are i cluded i Cla s A whereas gl s fib r and built p mica with a mall p oportion of o gan c materi l are in Cl B S me f the be t org c film mate i l have been h wn by te t to b uit ble for Cla B t mp ratures al S licone ompo nd il c ne treated Clas B material a d fluoroc rbo sucl as Teflon a e in Cla s H The tl rm l re i ti ity of u ual in ulating materials is drop of bout 200 C/(watt)(in) of he t flow a d allowan e mu t be made for the *temperature* d ffe enc ac the in ulation thi kness Th tand rd perm t de iati ns from the nomin l tem per ture l mits depe ding on the s ze and type of quipment and the i t nded serv e

Insulation tests Servic xperience is requ red to pro e th t n in ul tion sy tem is fully satisfac t ry b t l fe te ts on materials and n complete sy tems will sh ten the t me needed for the r eval u t n The Ame c n Inst tute of Electric l Eng n er pr v des number f t st pr cedure for th pu po e these p o id for xposu es of s m ples of ulat g mater als or model to peated y les of high tempe ture and v ltage check un t l fail r ur By plott g loga thm c lif s

l t wall
$V = 0$
K
vl r
$K = 3\pm$
d ct
$V = E$
a
b
$\frac{bE}{K+b}$
$\frac{KaE}{K+b}$

Eff t f d l ct c o t t K b tw d ct rs d l t w ll lt g d t but

Epoxy resins These are used as insulation of joints A liquid and a powder are mixed and heat is given off The chemical action sets it to a solid which is not flexible but has good electrical and mechanical properties

Heat insensitive insulations The effect of heat has no function in establishing the properties of the insulating materials in this group

Paper Paper insulation in multilayers oil impregnated and protected from moisture by a lead sheath is an old standby It is popularly used at voltages over 15 000 volts It has good electrical characteristics which change with age Its weakness is the lead or similar sheath which must be in perfect condition to keep the cable dry and operating Lead is subject to crystallization and electrolysis which can perforate it

Varnished cambric This is a eries of thin layers of varnished cloth Its electrical properties are not as good as paper oil cable and it requires the same moisture and mechanical protection usually a lead heath It is used at lower voltages

Nitrogen gas This is used to a considerable extent as an insulation for high voltage applications It is used under pressure in a pipe containing the conductor

Magnesium oxide This is a novel insulation for low voltages but rather high temperatures It is enclosed in a copper tube and carries the conductor at its center It is good for wet and dry locations and in special applications it may be used to 250 C

Asbestos Besides its heat insulating properties asbestos is an electric insulator to some extent particularly if impregnated with some waxlike substance It usually requires a water impervious sheath and is used for relatively low voltages It is also used in combination with plastics or varnished cambric *See* ASBESTOS [A S D]

RIGID INSULATION

Besides their use as flexible coverings for wires and cables insulating materials are employed in molded or built up form as components of rigid structures This rigid insulation must provide mechanical strength and stability of form as well as a dielectric barrier Mica glass porcelain and the thermosetting resins are the principal rigid insulating materials but these may be used in combination with any of the flexible materials

Mica A mineral of finely laminated structure and easy cleavage mica flakes are flexible tough and highly resistant to heat Mica is most often employed in the form of splittings about 1 mil thick which may be snowed on to heets of thin paper or glass fiber bonded with a suitable arnish and applied in multiple layers of tape Finely divided mica is used with epoxy or other resins to make a mica paper without separate backing Ground mica is used as a filler in molded insulation *See* MICA

Glass An amorphous material glass ordinarily consists of a mixture of silicates borates phosphates and other materials with silica SiO forming 50–90% of the total content It is employed in a great variety of compositions Blown and cast forms are used Glass yarn or cloth made of fibers 0 2–0 3 mil in diameter is also employed *See* GLASS AND GLASS PRODUCTS

Porcelain This is a hard brittle and imperviou material made from feldspar quartz, clay and other minerals The materials are finely ground intimately mixed in a liquid state molded into the desired shape while plastic dipped in glaze and fired at a high temperature *See* PORCELAIN

Uses of rigid insulation Rigid electrical insulation is u ed for supporting conductors and pacing them apart in a gas or liquid environment where the air or other surrounding medium is relied upon to provide the needed dielectric strength except at the supports Here the chief requirements are high surface creepage resistance and high strength to withstand the imposed mechanical forces including the shocks from short circuit currents The insulation must be impervious to water so that it will retain its high electrical re istance when washed or exposed to the weather and for the higher voltages it must be able to withstand arc discharges over the surface

For the highest voltages as for power tran mission lines the conductors are hung on strings of suspension insulators or supported on bushing These are made of glazed porcelain with a eries of skirts to lengthen the creepage paths and provide maximum resistance to flash over For medium voltages the bushings may be made of glass or molded plastics

For low voltages as for industrial control equipment and household appliances and where many conductors need to be closely spaced thermo etting plastic compounds are u ed chosen for their structural rigidity high surface creepage re istance ease of manufacture and low cost Besides a wide variety of synthetic compounds such as phenolic melamine and polyester resins composite materials such as phenolic resin coated cotton or asbestos fabric and impregnated wood are used

When the conductor spacing is too small for reliance on the dielectric strength of the surrounding gas or liquid as in transformers and rotating machines the rigid insulation must form a sealed barrier of high dielectric strength over the entire conductor surface The requirements are especially se ere for the slot embedded conductors of rotating machines where the insulation thickness must be held to a minimum and where part of the surface may be exposed to high velocity cooling air often containing fine particles of conducting material such as carbon dust

In general the windings of electric machines consist of stranded conductors arranged in erie or parallel connected coils or both each with one or more turns Thu three principal kinds of insulation are required for apparatus windings for the strand f r the turns and for the complete coil The strand insulation must be flexible enough to

re ch a val d term ned by radi tion a d sol d cond ction A few m teri ls ha e such fin pores that at atmo pheric p e ure their d mens ons are mall r tha the me n fr e p th of a r Such in ul t o h conduct itie l th n th t f t ll air [C.B BR]

B bl og phy H S Ca lslaw and J C Jaege *C duct o of He t i Sol ds* 2d ed 1959 W H Ma Ad ms *H at Tra m ss* 3d ed 1954 J D V rschoor and P Greeble H at transfer by gas cond cti n nd rad ati in fib s ns lations *Tra ASME* 74(6) 961 968 1952 G B Wilkes *Heat I sul t o* 1950

Insulation resistance testing

The test ng of the ele tri al e i tance f d le t i m te al r i sul t r *Insul t n* res stance s m as ed in megohms It o st of tw c nt but ing fa to (1) the ol m res stance resulti g f om the e t ce to curre t flow thr ugh the l ume f the mat rial and (2) th surfa e res st an e du to the re tanc to current flow er the urface of th mat r al The e two resistances are elect i ally n p rall l and it i mp s ble t sep a ate th m a gl m a urem nt If b sic in l t g p opert s f a materi l ar be ng tud ed judi i s h i f mpl i and el ct od c n fig t n an emph size ne ff t o r th other so that re able evaluating d ta of ch f ctor an be bt n d

If the nd t ons f m urement do n t p rmit h co t l as the ch cki g of in ulat on res t nc f l rg g ne to w nd ng the t st ng dit a d phy c l r g m nt must be evaluated r f lly t dete m n wh h, f either f ct t d m a t and wh th r t the te t w ll p odu e the des r d l at of the wind n Of ten only th t tal nsul t n res stanc is r qui ed nd i d du l aluation of th f e nd l me ffect need ot be m d E pt fo the mplest f m u em nt uch th e tan of ea p t t rmi l r th point to-p int i tan e f a w t h th u f a g a d c t is s e t al fo p ec se and a rat e It

Th t ta alue f the pp rent la t n res t nc r te t u rent ch ges w th t me d i th m f th e pr ple compo nts (1) the ur nt r q ed t ch ge the pa t c f th nt ct g elect od (th s usually c mpl t d i m o r mill ec nd les th cap itan e nd t rnal i t a e both l rge) (2) the rrent du t d lect absorpt (y la t m tes day) d fin lly (3) th c n l ctio c t h h i d t tr ath r than appa nt in lat t

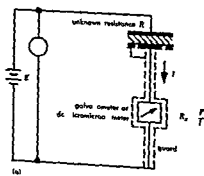
Bec u f th d ti it ecessary t p c fy f ll ll t t nd t of test volt g t m f re t n rr nt m u me t afte appl c tio f lt g t mpe t h m d ty l t ry p if th mpl m t be g u ded it m y be neces r t se a h ghly l ted po s pply S

DIELECTRICS INSULATOR ELECTRIC RESISTANCE ELECTRICAL RESISTIVITY ELECTRICAL

Guarded deflection method This method for measuring insulat n resistance illustrated by Fig l uses the ltmeter ammeter method (*see* RESIST ANCE MEASUREMENT) The voltage is mea ured with a voltmeter of su table range the current i meas ured by a calibr ted gal anometer with an Ayrton sl unt for r nge exten ion or a vacu m tube dc am pl fier calibrated as a m cromicroammeter with ap propr te mult pliers

A mod f cation of this method which perm ts the compar so of a high re i tance standard with th i sulati n re stance under test is shown in Fig 1*b* In th s meth d neither the test volt g nor the curr nts need be kn wn since the te t resi tance is propo tional to the omparison tanda d and the rat o of two currents

In ea h of the e c r uits the requ ite guarding of the te t equ pme t is shown by dotted line with the guard f the ample c nnected to the equip-ment guard It s e sential that all of the qu p-m nt hown with the gu rd line be mounted on th gua d plate or ci cuit H wever the insulation requ rem nts betwee gua d and me suring circuit are not severe Thi in ulation shunts the i ternal re st nce of th measuring c rcuit nd ther f re need o ly b 10–100 t mes this alue t minimi e the error f om th s sou ce If an ele tron c micro-mi roammeter i u ed it circuits including such



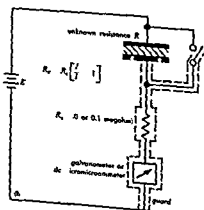


Fig l Ci c t f g d d d Re t me m t of f t t c ( ) Voltmet -amm t m thod (b) C mp o m thod

absolute temperature on an inverse scale and ex trapolating back to the proposed operating temper ature the life expectancies of alternative mate rials and systems may be compared

[P L A]

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Insulation heat

Materials whose principal purpose is to retard the flow of heat Thermal or heat insulation materials may be divided into two classes bulk insulations and reflective insulations The class and the material within a class to be used for a given application depend upon such factors as temperature of operation ambient conditions mechanical strength requirements and economics

Examples of bulk insulation include mineral wool vegetable fibers 85% magnesia calcium silicate with asbestos vermiculite silica aerogel diatomite and insulating fire brick They retard the flow of heat breaking up the heat flow path by the interposition of many air spaces and in most cases by their opacity to radiant heat

Reflective insulations are usually aluminum foil or sheets although occasionally a coated steel sheet an aluminumized paper or e en gold or silver surfaces are used Their effecti eness is due to their low emissivity (high reflectivity) of heat radiation

Thermal insulations are regularly used at temperatures ranging from a few degrees above absolute zero as in the storage of liquid hydrogen and helium to 3000 F in high temperature furnaces Temperatures of 4000–5000 F are encountered in the hotter portions of missiles and rockets the temperature exposure lasting only minutes or seconds so that insulations that would be destroyed by protracted exposure to these temperatures are successfully used

Heat flow The distinguishing property of bulk thermal insulation is low thermal conductivity Under conditions of steady state heat flow the following empirical equation describes the heat flow through a material

$$\frac{q}{A} = k \frac{A(\theta_2 - \theta_1)}{l}$$

where q = time rate of heat flow A = area θ_2 = temperature of colder side θ_1 = temperature of warmer side l = thickness or length of heat flow path and k = thermal conducti ity representati e values being listed in the table For a given thickness of material exposed to a gi en temperature

Thermal conductivities of selected solids

M t l	D ty lb/ft	Temp F	Co d ti ty k† Bt /( )(h) (ft)(F)
Asbest s cement bo d	120	75	4
C tt f ber	0 8 0	75	0 6
Miner l wool fib o ock l g o gl ss	1 5–4 0	75	0 27
In l ting board wood or cane f be	15	75	0 3
Fo m d pl t cs	1 6	5	0 9
Gl			3 6- 3
Ha dwoods typical	45	75	1 10
Softwoods, typ cal	3	75	0 80
C ll l gl ss	9	75	0 40
F d (4% m st c nt nt)	100	40	4 5
S lty cl y l am (0% m isture co tent)	100	40	9 5
Gypsum or pla t r board	50	75	1 1

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† Typ l u t bl f g n g c lc l t

difference the rate of heat flow per unit area is directly proportional to the thermal conducti ity of the material

In the unsteady state or transient heat flow the density and specific heat of a material have a strong influence upon the rate of heat flow In such cases thermal diffusivity $\alpha = k/\rho\, C_p$ is the important property Here ρ = density and C_p = specific heat at constant pressure In the imple ca e of one dimensional heat flow through a homogeneous material the go erning equation is

$$\frac{d\theta}{dt} = \alpha \frac{d^2\theta}{dx^2}\Big|_0^l$$

where t = time and x is measured along the heat flow path from 0 to l

Thermal conductivity In general thermal conductivity is not a constant for the material but varies with temperature For metals and other crystalline materials conductivity decreases with increasing temperature for glasses and other amorph us material conducti ity increases with temperature Bulk insulation materials in general behave like amorphous materials and have a positive temperature coeff cient of conducti ity

Thermal conductivity of bulk in ulation depend upon the nature of the ga in the pores The c n ducti ities f two in lations identical except for the gases filling the pore paces will differ by an am unt clo e to the differen e in the conducti itie of the two ga es

Increasing the pres ure of the gas in the p re of a l ulk in ulati n has little effect on the conduc ti ity even with pre ure of e eral atm phere Decrea ing the pre sure l little effect intil the mean free path f the g i in tl e ord r of magni tude of the dimensions of the pore Bel w thi pre sure the c nduct ity decr a rapidly i ntil it

s a d t define an ı tegral t an form Mo e ge rallȷ the int g al may be a m ltıpl ıntegral and th fun t f G ϕ may d pend on larger num be of var bles Equatı (1) tl ght of a tran f rm g whol cla r pace of funct on $\phi(y)$ t an tl er cla of fu ct on $f(x)$ The fun tı n $G(x\,y)$ ıs the kern l of the tra f rm On of the ımp rtant u e f such a tran fo m ı ba ed n the f ct that a pr bl m p d ın one of the tw pa e ı q t n may b mo e ea ıly ol ed ın the other F r e ampl a diff re tıal qı atı n to be l ed fo th f n tı n $\phi(y)$ ma b c me an alg br c quat on f r the unknown f ct on $f(\ )$ S e LAPLACE TRA SFORM

The two b c problems fo any ıntegral t ansform a e ın e s on and repr entation I ın e s n the aım s to rec e $\phi(y)$ fr m $f(x)$ the ke n l $G(x\ )$ beıng kr wn Th t Eq (1) ı tho ght of an ı tegral equ t n (of th fir t k nd) t be l ed f the nk own f n tıon $\phi(y)$ A me s f alculatıng $\phi(y)$ fr m $f(x)$ call d an ı n f rm l and ın ıts pr n the t ans f m chıev s m m m utılıty ı c xpl cıt p s age f m ea h pac to the the thus s ed In ep tatıo the qu st n ı wh ch f t ns $f(x)$ m y b wrıtt n r ep e ted ın the f rm (1) Th t ıs one a k wh ch f n t ns $f(\ )$ w ll m ke Eq (1) l ble f r $\phi(y)$ U u llv th s p blem becomes more t a tabl when th solut $\phi(y)$ a e r t cted to s m sub pa e uch a th l of p t e r bound d fun tı

Inversion theory In ma y ca es wh e th n p blem h been olı d n ve op erat r h s d fferent al tegral per to ha been f u d d pendıng p h p n pa am t r wh h a mpl h ıt ı e sı n It may b d t d by $O[f(\ )]$ Th me s that fo each al f th p am ter t me per tı n O on $f(x)$ d f ed F example, ı mıght be 3 d th ope at m ght t of c mp t ng the th d de ı a t of $f(\ )$ S ppo e that O appl ed ı Eq (1) prod c

$$O[f(\ )] = \int_{-\infty}^{\infty} G(\ y)\phi(y)\,dy \qquad (2)$$

wl $G(\ y)$ s a ew kernel f ch t In fa r able a th nteg l (2) ppr hes $\phi(\ )$ a t pp a he a t ble l m t fo xample when G pp a hes th Dı a δ fun t n $\delta(x-y)$

An ımport t pec l a e of Eq (1) th n l ı n tr f rm wh th kern l ıs fu c t $f(\ -y)$

$$f(\ ) = \int_{-\infty}^{\infty} G(\ -y)\phi(y)\,dy \qquad (3)$$

A q al nt f m of Eq (3) ı

$$F(\ ) = \int^{\infty} K(xy)\Phi(y)\,dy \qquad (4)$$

th h g f ı ble = e $y = e^{-}$ e rr e Fq (4) ı ı Eq (3) fte ıtable h ng ın t ı

Transformation formulas Many f th l l tr f rm ha be n n med f r the r gı al r pr nc pal ınve t gat r A few of the more ımportant one can be lısted wıth the names rd narıly at tached t them

For Eq (1)

A B later l Laplace	$G(x\,y) = e^{-xy}$		
B Fou ı r	$G(\ \ y) = e^{\ xy}$		
C. Mell n	$G(x\,y) = y^{x-1}$		$y > 0$
	$= 0$		$y < 0$
D Stieltjes	$G(x\,y) = (x+y)^{-1}$		$y > 0$
	$= 0$		$y < 0$

For Eq (3)

E. D chlet	$G(x) = x^{-}\ \sin x$	
F Fej r	$G(\ ) = x^{-2}(\ \text{ın}\, x)^2$	
G F actional (Weyl form)	$G(\ ) = (-x)^{\mu-1}$	$x < 0$
	$= 0$	$x > 0$
H Hılbert	$G(x) = x^{-1}$	
I P ard	$G(x) = e^{-\lvert\ \rvert}$	
J Po sson	$G(x) = (1 + x^2)^{-1}$	
K. Laplace (un lat ral)	$G(\ ) = e^x e^{-e^x}$	
L. St eltjes	$G(x) = \text{s ch}\,(x/2)$	
M We erstra s o Gauss	$C(\ ) = e^{-x}$	

For Eq (4)

N Fou ı cos ne	$K(x) = \cos x$
O Four sıne	$K(\ ) = \ \text{ın}\, x$
P Hankel	$K(x) = \sqrt{x}J\ (x)$
Q Laplace (u ılateral)	$K(x) = e^{-}$
R Me ȷ r	$K(x) = \sqrt{x}K\ (x)$

He e $J\ (x)$ ı a Be el fun t on and $K\ (x)$ a modified Bes l funct o Certaın t ansform re l sted tw e be au e of the r f e ju nt appearance ın two eq ı le t forms In fact all of the abo e are con lutıon t an f rm e cept A B and C. It c n b en al o that A a d C are the same t ansf rm (et $y =$ ın C)

Representation Th ır r on theory for a l rge cla s f on olut on tran f rm h s b en com pl ted Ope at on l c l ulus a gu d to the m thod (se OPERATOR THEORY) If the symb l D st nd f r d ffe ent atı w th respect to x l ut ı n theless tr ated a a numbe ın the famılı rıe

$$e^{tD} = \sum_{k=0}^{\infty} \frac{t^k}{k!} D^k$$

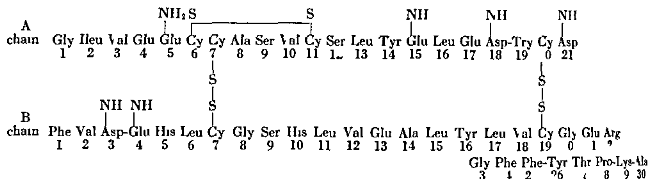
one ı l d t make the d finıtıon

$$e^{tD}f(x) = \sum_{k=0}^{\infty} \frac{t^k}{k} D^k f(x) = f(x+t) \qquad (5)$$

sı e the s r s ( ) p e ı ly the Maclaurın ex p n on of $f(x+t)$ ıf D^k ı allowed t me n a kth derı atı e

N w c ns de the b l t al Lapl e t n fo m f $G(t)$ n Eq (1) den t g ıt by $1/E(\ )$

$$\frac{1}{E(\ )} = \int_{-\infty}^{\infty} e^{-}\ G(t)\,d \qquad (6)$$



Structure of cattle insulin

1924 demonstrated that the anterior pituitary plays an important role in the etiology of the diabetic state of an organism See PANCREAS

The biological potency of insulin preparations is given in terms of an international unit (IU) defined as the hormonal activity of 0 125 mg of an international standard preparation It is generally assayed by injecting the hormone subcutaneously into fasting rabbits and then determining the rate and extent of the lowering of the blood sugar level Pure insulin possesses an activity equivalent to 24 IU per milligram Insulin loses its physiological activity when treated with alkali to pH 10 or with proteolytic enzymes like chymotrypsin

Insulin is a polypeptide with a molecular weight of approximately 6000 It is generally prepared from beef pancreas and this bovine insulin has been found to be composed of 254 atoms of carbon 377 atoms of hydrogen 65 atoms of nitrogen 75 atoms of oxygen and 6 atom of sulfur The insulin molecule contains 48 amino acids which make up two peptide chains (A chain and B chain) joined by sulfur atoms or —S—S bridges A complete description of the structure of bovine insulin was achieved by F Sanger and coworkers in 1954 The structural formula is depicted above where Gly is glycine Ileu isoleucine Val valine Glu glutamic acid Cy cystine Ala alanine Ser serine Leu leucine Tyr tyrosine Asp aspartic acid Try tryptophan Phe phenylalanine His histidine Thr threonine Pro proline Lys lysine Arg arginine

Insulin preparations from other species such as pig sheep horse and whale have also been examined by Sanger and coworkers and have been found to be similar in structure to the bovine insulin except for the amino acid sequence comprising positions 8 9 and 10 in the A chain of the molecule The biological potency of insulin has not been found to differ from species to species nor has it been possible to differentiate the various preparations immunologically [C H L]

Insulin shock

A treatment for schizophrenic psychosis introduced by Manfred Sakel in 1933 It is also known as coma treatment The patient receives a course of 20–50 treatments consisting of gradually increasing doses of insulin until coma is reached Patients are awakened by oral or intravenous applications of sugar or glucose See SCHIZOPHRENIA

The treatment is an empirical method not based on a satisfactory theory Reports about results of this treatment have always been contradictory ranging from enthusiastic reports of 80% recoveries to very conservative estimates in which the number of recovered patients hardly exceeds the rate of spontaneous remission Factors such as the general hospital atmosphere the attitude of the therapist and varying criteria of recovery explain such wide discrepancies

Administration of insulin coma treatment is a complex time and personnel consuming procedure For this reason and because fatalities have occurred and a number of patients have received lasting neurological damage insulin shock treatment has been on the decline It has been replaced largely by electric convulsive treatment and by drug therapy with tranquilizers and psychic energizers (*see* PSYCHIC ENERGIZER TRANQUILIZER)

In subcoma treatment the doses are kept small enough so that not coma but its prodroma such as *sweating drowsiness and hunger* are produced During this subcoma state the patient may be more amenable to psychotherapy *See* PSYCHOTHERAPY [F C R]

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Intaglio (gemology)

The name given to the type of carved gem stone in which the figure is engraved into the surface of the stone rather than left in relief by cutting away the background as in a cameo Intaglios are almost as old as recorded history for this type of carving was popular in ancient Egypt in the form of cylinders The cylinder as well as the more familiar form of intaglio was popular to impress seals on sealing wax Intaglios have been carved in a variety of gem materials including emerald crystalline quartz hematite and the various forms of chalcedony *See* CAMEO [R T L]

Integral transform

An integral relation between two classes of functions For example a relation such as

$$f(x) = \int_{-\infty}^{\infty} G(x\,y)\phi(y)\,dy \qquad (1)$$

ı a d t d fin an ntegral tra sform More gen e lly the tegral may be a mult pl integ l and the fun t on f G ϕ may d p nd on a l rger num b r f ariabl Equat on (1) ı thought f s tr form g a wh le la s or pac of functı n $\phi(y)$ nt a other cla s f f nct ns $f(x)$ The f n t n $G(xy)$ ı th ke n l f the tr n f rm On of the importa t u e f s h a t ansf rm ı ba ed on the f ct that a p oblem p sed ne of the two spa s in question may b m re a ly ol ed ın the ther For xample, d ffe enti l qu tio to be olved f th f n t on $\phi(y)$ may become an lgebra qu t o fo the unknown functı n $f(x)$ See LAPLACE TRANSFORM

The t b problem for any ıntegral tr n f rm are t rsion d rep s ntat on In inv r s on the a m ıs to o er $\phi(y)$ fr m $f(x)$ the kernel $G(\ y)$ be g k own Th t Eq (1) s tl ght f s ntegr l qu t n (f the first k d) t b l ed for th nkn wn fun tı n $\phi(y)$ A mean f calc lat ng $\phi(y)$ f m $f(x)$ s called a ın r ı frm l a d n l pre en e th tra s- f rm ach e es ma m m tıl ty ce expl c t pa age f m e h space to the oth ıs th as- u ed In r p ese tat n the q est n s which fu t $f(\ )$ may be written r rep ented ın th f rm (1) Th t ıs one a k wh ch functı s $f(x)$ w ll m ke Eq (1) l able fo $\phi(y)$ Us ally thı probl m be mes m e tractabl when the sol t $\phi(y)$ are r t cted to me ub pac s h as the cl f pos t r bounded f t n

Inversion theory In many c es whe the n p bl m h b e ol d an ın r n p r t r s h as a diff r tal r t g al perator h s been fo d d p ndı g pe hap n a p am t h h a ompl h tl s on It m y b d ted by $O[f(\ )]$ Thı m ans th t for a h lu of th par met r t me pe at n O r $f(\ )$ d fined F r ex mpl t might b 3 and th oper at m ght t f c mp tı g the third d t t e f $f(\ )$ S ppose that O pplied to Eq (1) p od es

$$O[f(x)] = \int_{-\infty}^{\infty} G(xy)\phi(y)\,dy \qquad (2)$$

wh e $C(\ y)$ a ew kern l f each t In fa or ll ase the ı tegr l (2) app oaches $\phi(x)$ as t pp oa hes u table l m t f e ampl wh C pproa hes the D c δ fu t o $\delta(\ -y)$

An mport t spec l ca e f Eq (1) the l t o t f rm wh the ke nel ı a func t ı (y)

$$f(x) = \int_{-\infty}^{\infty} C(\ -y)\phi(y)\,dy \qquad (3)$$

A ıu l nt f m f Eq (3)

$$F(x) = \int^{\infty} K(xy)\Phi(y)\,dy \qquad (4)$$

th h g f a bl = e y = → c rries Eq (4) t Eq (3) aft a s t ble hange ın n tat

Transformation formulas M ny f th cla al t n f rm h been amed for the ıg nal or pr nc pal ınve tıg tor A few of the more ımportant nes can be l ted with the names ordinarily at t hed to them

F r Eq (1)

A Bılater l Lapl c	$G(xy) = e^{-}$	
B Fou er	$G(\ y) = e$	
C Mellin	$G(xy) = y^{x-1}$	$y > 0$
	$= 0$	$y < 0$
D Stieltjes	$G(xy) = (x+y)^{-1}$	$y > 0$
	$= 0$	$y < 0$

For Eq (3)

E D r chlet	$G(x) = x^{-1} s n x$	
F Fej r	$G(x) = \ ^{-2}(\sin x)^2$	
G F a t onal (Weyl form)	$G(x) = (-x)^{\mu-1}$	$x < 0$
	$= 0$	$x > 0$
H H lbert	$(\ ) = x^{-1}$	
I P card	$G(\ ) = e^{-\|\ \|}$	
J Po ss n	$G(x) = (1+x^2)^{-1}$	
K Lapl c (nilate al)	$G(x) = e^x e^{-e}$	
L St ltjes	$G(x) = \operatorname{sech}(x/2)$	
M We erstrass or G us	$G(x) = e^{-x^2}$	

For Eq (4)

N Foure c s ne	$K(x) = \cos x$
O F ur e s ne	$K(x) = \sin x$
P Hank l	$K(x) = \sqrt{x}J\ (x)$
Q Lapl ce (unilate al)	$K(x) = e^{-}$
R Meıje	$K(x) = \sqrt{x}K\ (\ )$

H re $J\ (x)$ ı a Be l funct on and $K\ (x)$ a mod fied Bes el fun t n Certain tran for ns are l st d tw e becau e f th r frequent ppear nce n two qu le t f rms In fact all of the bo e are o v lut on t an f ms except A B and C. It c n be s en l that A nd C re the s m transf rm (set $y = e^{\ t}$ n C)

Representation Th ve s on theory fo a l rge cl s of onvolutı tran forms has been com plet d Ope atı al al ul s ıs a g ıd to th meth d (se OPERATOR THEORY) If the ymbol D st d for differe tıat n w th respect to x but ıs n nethel s t eat d as a numb r ın th familiar s r es

$$e^{tD} = \sum_{k}^{\infty} \frac{t^k}{k} D^k$$

n l d t mak the d fin tion

$$e^{tD}f(x) = \sum_{k=0}^{\infty} \frac{t^k}{k!} D^k f(x) = f(x+t) \qquad (5)$$

ı e the es (5) s p ecı ely the M claurin ex pansio of $f(x+t)$ f D^k ı llowed t me a kth d r vat

N w con d r th b lateral Lapl ce transf rm of $G(t)$ n Eq (1) den t g t by $1/E(\ )$

$$\frac{1}{E(s)} = \int_{-\infty}^{\infty} e^{-\ } C(t)\,dt \qquad (6)$$

Replacing s by D and using Eq (5) one has

$$\frac{1}{E(D)}\phi(x) = \int_{-\infty}^{\infty} e^{-tD}\phi(x)G(t)\,dt$$
$$= \int_{-\infty}^{\infty} \phi(x-t)G(t)\,dt$$
$$= \int_{-\infty}^{\infty} G(x-y)\phi(y)\,dy$$
$$= f(x) \qquad x - t = y \qquad (7)$$

If $E(D)$ were a number one could solve Eq (7) to obtain

$$\phi(x) = E(D)f(x) \qquad (8)$$

Finally reverting to the original meaning of D as a derivative one has in Eq (8) an inversion of Eq (1) by means of a differential operator $E(D)$

This argument is meant to be exploratory only but the result is accurate for a large class of kernels G and their corresponding inversion functions E In summary the inversion function is the reciprocal of the bilateral Laplace transform of the kernel It has been shown that the result is correct if for example $E(s)$ is the infinite product

$$E(s) = e^{b -} \prod_{k=1}^{\infty}\left(1 - \frac{s}{a_k}\right)e^{\ /\ k} \qquad (9)$$

where $c \geqq 0$ and the series of real constants

$$\sum_{k=1}^{\infty} a_k^{-2}$$

converges

For example if $K(x) = e$ then Eq (4) is the Laplace transform Expressed as a convolution transform as in Eq (3) it becomes

$$e\,F(e\,) = \int_{-\infty}^{\infty} G(x-y)\Phi(e^{-y})\,dy$$

where G is given in the above list as entry K The bilateral Laplace transform of this kernel is the familiar gamma function

$$\Gamma(1-s) = \int_{-\infty}^{\infty} e^{-\ t}G(t)\,dt = \int_0^{\infty} e^{-t}t^{-}\ dt$$

whose reciprocal has a well known expansion in the form of Eq (9)

$$E(s) = \frac{1}{\Gamma(1-s)} = e^{-\gamma} \prod_{k=1}^{\infty}\left(1 - \frac{s}{k}\right)e^{\ /k}$$

Here γ is Euler s constant In the present example Eq (8) becomes

$$e^{-\gamma D} \prod_{k=1}^{\infty}\left(1 - \frac{D}{k}\right)e^{D/k}e\,F(e^{x}) = \Phi(e^{-}\ )$$

or if $e \quad = t$

$$\lim_{k\to\infty} \frac{(-1)^k}{k!}F^{(k)}\left(\frac{k}{t}\right)\left(\frac{k}{t}\right)^{k+1} = \Phi(t)$$

This familiar inversion formula also serves to illustrate the operator O_t appearing in Eq (2) In the present case the operator is a differential one and the parameter t is an integer k which tend to ∞ *See* CONFORMAL MAPPING INTEGRATION

[D V W]

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Integration

An operation of the infinitesimal calculus which has two aspects The roots of one go back to antiquity for Archimedes and other Greek mathematicians used the method of exhaustion to compute areas and volumes A simple example of this is the approximation to the area of a circle obtained by inscribing a regular polygon of known area and then repeatedly doubling the number of sides The areas of the successive polygons are computable with the help of elementary geometry The limit of the sequence of these areas gives the area of the circle The area of each polygon can be regarded as made up of the sum of the areas of triangles with vertices at the center of the circle and so the process described is a constructive definition of an integral which is the limit of a sum Modern definitions of integrals as limits of sums are discussed in this article

The other aspect of integration is the process of finding antiderivatives that is for a given function $f(x)$ to find another function $g(x)$ whose derivative is $f(x)$ This aspect is related to the first by the fundamental theorem of integral calculus so both processes are called integration

Sir Isaac Newton emphasized the antiderivative aspect of integration and his work shows how much can be done in the applications of integral calculus without introducing limits of sums However limits of sums lead to very fruitful theoretical developments in the theory of integration as in the notion of multiple integrals for example and hence lead to a wider variety of applications Leibnitz the seventeenth century mathematician inspired the development in this direction but many years elapsed before the theory was given a firm logical foundation In the early nineteenth century A L Cauchy gave a clear cut definition of the definite integral for continuous functions and a proof of its existence Later G F B Riemann discussed the integral for discontinuous functions and gave a necessary and sufficient condition for its existence Thus the most generally used definition of the integral as the limit of a sum has come to be called the Riemann integral

Riemann integral The precise definition f the Riemann integral f r a real function f of one real variable x on a finite interval $a \leqq x \leqq b$ may be formulated as follows Let P be a partition of the interval $[a\ b]$ into n subintervals by points t where $t_{\ 1} < t_i\ t_0 = a\ t \ = b$ and consider a sum S of the form

$$S = \sum_{i=1} f(x\ )(t \ - t_{-1}) \qquad (1)$$

where $t_{i\ 1} \leqq x_i \leqq t_i$ The sum S depends not only on

the p rtiti n P but on the cho ce of the intermed te po nts x It may happen that th um S app oaches a defin te l mit I wh n the maximum f the numb rs $(t - t\ )$ te ds to z r nd in thi a e I is alled th R emann i tegral (or the defi te i tegral) f f f m a t b a d s denoted by the Le bn tzian symbol

$$\int^b f(x)\,dx$$

Al o f s s id t be integrable on $[a\,b]$ When f is a n t o fu ti n w th posit e value on the nterv l $[a\,b]$ the int gr l h s a mple ge m tr I nte pr tat o as the a ea bounded by the x a the ord n t s $x = a$ nd $x = b$ and th gr ph of $y = f(x)$ (F g 1) It i con ni t to define

$$\int_b f(\ )\,dx = -\int^b f(x)\,dx$$

F r funct f and g which a e ntegrable on [b] th i t gral has th f ll wi g pr p rti s

(i) f i nt g able n e ry sub nterval f [b]

(i) For very tr ple of po nt d and in $[a\,b]$

$$\int^d f(x)\,dx + \int f(x)\,dx = \int f(x)\,dx$$

( ) $f(x) + g(\ )$ integr bl and

$$\int [f(\ ) + g(\ )]\,d = \int^b f(x)\,d + \int^b g(x)\,dx$$

( ) $f(\ )g(x)$ i integr bl and in part cul r $f(x)$ t g bl for ev ry re l n mber c and

$$\int cf(x)\,d = \int f(x)\,dx$$

( ) If $f(x) \le g(x)$ on $[a\,b]$ th

$$\int^b f(\ )\,dx \le \int^b g(\ )\,d$$

( ) $|f(x)|$ s tegrabl a d

$$\left|\int f(x)\,dx\right| \le \int |f(\ )|\,dx$$

It c n be pr ed that f n ti n f i t gr ble n [b] f d i if the tw c nd t ns f llow ng ar t fied f i bo nded o [b] nd th t of po nt wh f i d sc t u s ca b n lo d in es (po t l fi te) f tervals th m f hose l ngth arb t a ly e l ze

Ant derivati es T dev l p the fu dame tal theorem f t g l c l l l t u be a n bl in the interval $[a\,b]$ on which f is i tegrable then

$$\int f(\ )\,dx$$

is a function wh ch may be denoted by $I(u)$ If f is continu us o $[a\,b]$ then f is i tegrable and it is al o true that $I(u)$ has a deriv t ve $I'(u) = f(u)$ Now l t h be any antid r vati e of f that is $h'(u) = f(\ )$ on $[a\,b]$ Then $I'(u) - h'(u) = 0$ so $I(u) - h(u) = \text{constant} = -h(a)$ by the theorem of the mean for derivativ s and the fact that $I(a) = 0$ o

$$I = I(b) = h(b) - h(a)$$

Th s is the f nd m nt l theorem of integral c l u lus and it how th t *definit integrals may be* cal c lated by the proce s *of find ng antide i atives* F r th r a on ant deri ati es a e l equ ntly called ndef n te int g al and denoted by $\int f(x)\,dx$ and pe i l methods f f d ng indefin te integr l f r f equ ntly o cur ing functi n ccupy a la g part f el m tary alculu Th pri cipal meth d are utli ed in the next s ct on The standard n ta t o f an i defi te ntegral of $f(x)$ s

$$\int f(x)\,dx$$

Elementary methods of integration Ob iously ach formula f r d ff r nt at on yi ld formula for definite i tegrat n

Method of s b tit ti F om the e i d fin te nteg al add t n l f rm la can be obtained by the m thod of ub t tut n which is ba ed on the ch n ule f r differe ti ti g c mp s te f nct ons F ex mple fr m the fo mul

$$\int x^m\,d = \frac{x^{m+}}{m+1}$$

n obta ns

$$\int(\ ^2 + x^2)^m\ d = \frac{(a^2 + x^2)^{m+1}}{2(m+1)}$$

by th subst tut on $v = a +$ and

$$\int \ n^m x \cos x\,d = \frac{s\ n^{m+1} x}{m+1}$$

by the s l st t t n $v = s\ n\ x$

M thod f pa tial f tions In c e $f(x)$ is a q ot nt of two polynom l i x $f(x)$ may be repr ented a a m of a polyn mi l nd t rms of th f rm

$$\frac{1}{(ax+b)^m} \qquad a \ne 0 \tag{2}$$

$$\frac{A\ + B}{(cx^2 + d\ + e)^m} \qquad c \ne 0\ d^2 - 4ce < 0 \tag{3}$$

whe m a po ti e i teger and the coeffici nt a real This s alled th method *of part al f ac t ns* It a tu l e it o r qu r s a knowledge of the fact r f the denom nat r f $f(x)$ T rms of *th form* (2) ha e known indefin te int g al Term f the f rm (3) w th $m = 1$ c n al o b

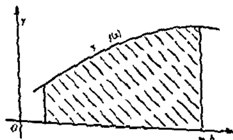


Fig 1

integrated by elementary formulas When $m > 1$ a term of the form (3) can be written as a sum of terms of the form

$$\frac{\alpha}{(ax^2 + dx + e)^{m-1}}$$

and

$$\frac{(\beta x + \alpha)(2cx + d)}{(cx^2 + dx + e)^m} \qquad (4)$$

By the process of integration by parts the indefinite integral of a term of the form (4) can be expressed in terms of the integral of a term such as (3) with m replaced by $m - 1$ Reduction formulas of this type are given in standard tables of integrals

A rational function of $\sin x$ and $\cos x$ may be integrated by the method just described after the substitution $u = \tan(x/2)$ has been applied This substitution reduces the problem to the integration of a rational function of u Various functions involving radicals can be integrated by means of trigonometric substitutions or by other substitution which reduce the problem to the integration of a rational function For example by setting $u = a + bx$ one finds

$$\int x^m(a + bx)^p\, dx = \int \left(\frac{u - a}{b}\right)^m u^p \frac{du}{b}$$

and when m is a nonnegative integer the right side may be multiplied out and integrated by the power formula even though p is a fraction

Integration by parts This is a very powerful and important method It follows from the formula for differentiating a product namely

$$d(fg) = f\,dg + g\,df$$

After the terms are rearranged and integrated

$$\int f\,dg = fg - \int g\,df$$

or

$$\int fg'\,dx = f(x)g(x) - \int gf'\,dx$$

where the arbitrary constant as usual has been omitted As an example consider

$$I = \int \frac{2x^2\,dx}{(x^2 + 1)^m}$$

which is a special case of (4) Let $f = x$ $g' = 2x/(x^2 + 1)^m$ Then $f' = 1$

$$g = \frac{1}{(1 - m)(x^2 + 1)^{m-1}}$$

$$\text{so } I = \frac{x}{(1 - m)(x^2 + 1)^{m-1}} - \frac{1}{(1 - m)} \int \frac{dx}{(x^2 + 1)^{m-1}}$$

The indefinite integrals of many of the commonly occurring functions are given in table of integrals in handbooks and textbook

The elementary functions are those expres ile by means of a finite number of algebraic operations and trigonometric and exponential functi ns and their inver es The integrals of many elementary functions are known to be not element ry so they define new functions A number of these are suf ficiently important o that their values have been tabulated Examples are

$$F(k, x) = \int_0 \frac{dx}{\sqrt{(1 - x^2)(1 - k^2x^2)}} \qquad (k^2 \neq 1)$$

$$\mathrm{Si}\, x = \int_0 \frac{\sin x\, dx}{x}$$

$F(k, x)$ is called an elliptic integral of the fir t kind The inverse of $u = F(k, x)$ is an elliptic function called the sine amplitude of u and denoted by x sn u (*see* ELLIPTIC FUNCTION AND INTEGRAL) Some of the nonelementary functions have been included in tables of integrals

Improper integrals This term is u ed to refer to an extension of the notion of definite integral to ca es where the integrand is unbounded or the domain of integration is unbounded Consider fir t the case when $f(x)$ is integrable (in the en e defined above) and hence bounded on every interval $[a + \epsilon, b]$ for $\epsilon > 0$ but is unbounded on $[a, b]$ Then by definition

$$\int^b f(x)\,dx = \lim_{\to 0} \int_{+}^{b} f(x)\,dx$$

provided the limit on the right exists For example if $f(x) = x^{-2/3}$

$$\int_0^1 x^{-2/3}\,dx = \lim_{\to 0} \int^1 x^{-2/3}\,dx = \lim_{\epsilon \to 0} 3[1 - \epsilon^{1/3}] = 3$$

Similarly

$$\int_{-1}^0 x^{-2/3}\,dx = \lim_{\to 0} \int_{-1}^{-} x^{-2/3}\,dx$$

$$= \lim_{\epsilon \to 0} 3[(-\epsilon)^{1/3} + 1] = 3$$

When $f(x)$ is integrable on every finite subinterval of the real axis by definition

$$\int^{+\infty} f(x)\,dx = \lim_{b \to +\infty} \int^b f(x)\,dx$$

$$\int_{-\infty} f(x)\,dx = \lim_{b \to -\infty} \int_b f(x)\,dx$$

provided the limits n the right exi t More general cases are treated by dividing the real axis into pieces each of which satisfies one of the c ndit ons just sp ecified For examp le

$$\int_{-\infty}^{+\infty} x^{-6/} \,dx = \lim_{\to -\infty} \int^{-1} x^{-6/3}\,dx$$

$$+ \lim_{\delta \to 0} \int_{1}^{-\delta} x^{-6/3}\,dx + \lim_{\to 0} \int^1 x^{-6/3}\,dx$$

$$+ \lim_{b \to +\infty} \int_1^b x^{-6/3}\,dx \qquad (5)$$

Because the econd and third f the limits on the right do not exist

$$\int_{-\infty}^{+\infty} x^{-6/3}\,dx$$

d e n t xi t Howe er it i ometime u eful to a

gn a valu to t, alled the Cau hy pr nc pal value by r placi g th defi t on (5) by

$$\int_{-\infty}^{\infty} x \quad {}^{3} d_x = \lim_{\epsilon\to 0}\left[\int_{-1}^{-} x^{-/3}\,dx + \int^{1} x^{-8/3}\,dx\right]$$

$$+ \lim_{b\to+\infty}\left[\int_{-b}^{1} - {}^{3}\,dx + \int^{b} x \quad {}^{3}\,dx\right]$$

I th pa ti ila c e the al i is ze

Th pre ed g defi ti ns apply to e when *th* i t grand $f(\ )$ bou ded x pt i a b trarily mall ne ghbo hood of fin te s t f p ts I the l i g y s of the netee th ce tury a io t n w e m de to more g al ca e Then Hen l b gu p odu ed a c mp r t ely mple g ne l theory f r the a of ab l t ly n g nt i t eral The integ al of Lebe gue w ll b d s d bel w Th t gr l f D njoy includ b th non ab l t ly on e ge t nt g al nd the i teg al of Lebe g

Multiple integrals Th c cept call d the R e m i t gral b e t ded t f nctu n f e l a bles Th f a fu ct n of tw al l ill trat ffi ntly the dd t nal feature h h a e To beg w th l t $f(\ y)$ den t a r al fun t d fi ed n recta gl

$$R\ a \leqq \ \leqq b \qquad c \leqq y \leqq d$$

Let I be a p rt t n f R into non erl pp ng ectangles R w th ar A nd l t $(x\ y)$ b a po t f R S t

$$S = \sum f(\ \ y)A$$

I a th m S t d t defi it l m t I when th m m m d g n l f ect ngl R t nd to ze th f i d t be tegrable o R and th l mit I lled th R t gr l f f r R It ll l de ote l h by th abbre ted symbol

$$\iint f$$

I roperti es r pond g t thos umb d ( ) t) a be p d f th d bl t grals e pt th t pr p rty ( ) h ld w e d a foll w ( ) If th ect gle R s the um of tw ect ngl S l T then

$$\iint_R f = \iint_S f + \iint_T f$$

Nec sary d uffi nt o d t s f a fun t $f($) t be nt g bl e R be t ted a f l l w f bo nded R nd th t f po t wh f d scont be e l ed r es f ec t gles th m f wh e r as i b t r ly n a t

T d f th nt g l f a fu t n $f(\ y)$ a m g l d m D h t d fi ed ppo e th t D l sed a ecta gl R a d t

$$F(\ \ ) = f(\ \ ) \quad D$$
$$F(\ y) = 0 \quad t \ f\ D$$

Then f is said to be i t grable over D in ca e F is i tegrabl over R and

$$\iint_D f = \iint_R F$$

by defin tion

Wh n the funct on $f(x\,y)$ i continu us on D and D s d fi ed by inequal t es of th form

$$a \leqq x \leqq b \qquad \alpha(x) \leqq y \leqq \beta(x)$$

wh e th funct ons $\alpha(x)$ and $\beta(x)$ ar continuous the double i tegral f f ver D always exi ts and may be epre ent d in term of two mple integral follows

$$\iint_D f = \int^{b}\left[\int_{(\ )}^{\beta(\ )} f(x\,y)\,dy\right]dx$$

In many s th s f rm la makes possible the eval uat on of th d ubl nt gral

Improp r mult ple tegrals ha be n defined n a ari ty of way Th re is n t spa e to discu the e d finit on a d their rel t ons here

Line surface and volume integrals A gen ral d us i n of c rves nd urfaces requires an ex tended treati e The f ll w ng outl ne is re tr cted to the s mpl t case

A c rv may b defined s a cont nuous image of an op n nte al Th s a curve C in the xy pla s gi en by p r of ntinuo s funct ons of on var a bl

$$x = f(u) \qquad y = g(u) \qquad a < u < b \qquad (6)$$

wher as a urve n p c g ven by t iple f ch fun t The mapping (6) s mo e p operly called r pre e tati n f a urve and a cur e is then de fined s a su tabl las f su h r p e ent t ns. Note th t urve (6) s path r the than lo us Fo xample

$$x = \quad s\,u \qquad y = \ i\ \ u \qquad 0 < u < 4\pi$$

i the p th go ng twi e around th un t c cl

$$+ y^2 = 1$$

in th unterel kwi d r t on A curve c ll d smooth in c e th f ncti n f and g h ve continuous de u es $f'(\ )$ a d $g'(\ )$ wh ch are ne er s m l taneou ly e

Th l ngth of a mooth curv C m y b l fin d a

$$l(C) = \int \sqrt{[f'(\ )] + [g'(\ )]^2}\,d$$

wh n th s teg l ex ts (as p per o imp p r ntegral) Wh n the int gr l d n t t, th l gth f C i id t be fin te Th d fin t f l gth n te ms f th int g l may l e h wn to nc d w th th geom t defi t n in a m cl l ge la tha th cla f mo th ry When C h fi it l gth th posit n ect $[f(\ )\ g(u)]$ appr hes d f t l m t whe u te d to a t b wh ch a the d f th rv C A m th curv h t v ry p t a on ro t nge t e t r $T(u)$ with mpo e ts $f'(u)$ d $g'(u)$ so th t the

integrated by elementary formulas When $m > 1$ a term of the form (3) can be written as a sum of terms of the form

$$\frac{\alpha}{(ax^2 + dx + e)^{m-1}}$$

and
$$\frac{(\beta x + \alpha)(2cx + d)}{(cx^2 + dx + e)^m} \tag{4}$$

By the process of integration by parts the indefinite integral of a term of the form (4) can be expressed in terms of the integral of a term such as (3) with m replaced by $m - 1$ Reduction formulas of this type are given in standard tables of integrals

A rational function of $\sin x$ and $\cos x$ may be integrated by the method just described after the substitution $u = \tan (x/2)$ has been applied This substitution reduces the problem to the integration of a rational function of u Various functions involving radicals can be integrated by means of trigonometric substitutions or by other substitutions which reduce the problem to the integration of a rational function For example by letting $u = a + bx$ one finds

$$\int x^m(a + bx)^p\,dx = \int \left(\frac{u-a}{b}\right)^m u^p\,\frac{du}{b}$$

and when m is a nonnegative integer the right side may be multiplied out and integrated by the power formula even though p is a fraction

Integration by parts This is a very powerful and important method It follows from the formula for differentiating a product namely

$$d(fg) = f\,dg + g\,df$$

After the terms are rearranged and integrated

$$\int f\,dg = fg - \int g\,df$$

or
$$\int fg'\,dx = f(x)g(x) - \int gf'\,dx$$

where the arbitrary constant as usual has been omitted As an example consider

$$I = \int \frac{2x^2\,dx}{(x^2 + 1)^m}$$

which is a special case of (4) Let $f = x$ $g' = 2x/(x^2 + 1)^m$ Then $f' = 1$

$$g = \frac{1}{(1-m)(x^2+1)^{m-1}}$$

so
$$I = \frac{x}{(1-m)(x^2+1)^{m-1}} - \frac{1}{(1-m)}\int \frac{dx}{(x^2+1)^{m-1}}$$

The indefinite integrals of many of the commonly occurring functions are given in tables of integrals in handbooks and textbook

The elementary functions are those expressible by means of a finite number of algebraic operations and trigonometric and exponential functions and their inverses The integrals of many elementary functions are known to be not elementary so they define new functions A number of these are sufficiently important so that their values have been tabulated Examples are

$$F(k,x) = \int_0^x \frac{dx}{\sqrt{(1-x^2)(1-k^2x^2)}} \qquad (k^2 \neq 1)$$

$$\mathrm{Si}\,x = \int_0^x \frac{\sin x\,dx}{x}$$

$F(k,x)$ is called an elliptic integral of the first kind. The inverse of $u = F(k,x)$ is an elliptic function called the sine amplitude of u and denoted by $x = \mathrm{sn}\,u$ (see ELLIPTIC FUNCTION AND INTEGRAL) Some of the nonelementary functions have been included in tables of integrals

Improper integrals This term is used to refer to an extension of the notion of definite integral to cases where the integrand is unbounded or the domain of integration is unbounded Consider first the case when $f(x)$ is integrable (in the sense defined above) and hence bounded on every interval $[a + \epsilon, b]$ for $\epsilon > 0$ but is unbounded on $[a,b]$ Then by definition

$$\int_a^b f(x)\,dx = \lim_{\epsilon\to 0}\int_{a+\epsilon}^b f(x)\,dx$$

provided the limit on the right exists For example if $f(x) = x^{-2/3}$

$$\int_0^1 x^{-2/3}\,dx = \lim_{\epsilon\to 0}\int_\epsilon^1 x^{-2/3}\,dx = \lim_{\epsilon\to 0} 3[1 - \epsilon^{1/3}] = 3$$

Similarly

$$\int_{-1}^0 x^{-2/3}\,dx = \lim_{\epsilon\to 0}\int_{-1}^{-\epsilon} x^{-2/3}\,dx$$
$$= \lim_{\epsilon\to 0} 3[(-\epsilon)^{1/3} + 1] = 3$$

When $f(x)$ is integrable on every finite subinterval of the real axis by definition

$$\int_a^{+\infty} f(x)\,dx = \lim_{b\to+\infty}\int_a^b f(x)\,dx$$

$$\int_{-\infty}^a f(x)\,dx = \lim_{b\to-\infty}\int_b^a f(x)\,dx$$

provided the limits on the right exist More general cases are treated by dividing the real axis into pieces each of which satisfies one of the conditions just specified For example

$$\int_{-\infty}^{+\infty} x^{-5/3}\,dx = \lim_{a\to-\infty}\int_a^{-1} x^{-5/3}\,dx$$
$$+ \lim_{\delta\to 0}\int_{-1}^{-\delta} x^{-5/3}\,dx + \lim_{\epsilon\to 0}\int_\epsilon^1 x^{-5/3}\,dx$$
$$+ \lim_{b\to+\infty}\int_1^b x^{-5/3}\,dx \tag{5}$$

Because the second and third of the limits on the right do not exist

$$\int_{-\infty}^{+\infty} x^{-5/3}\,dx$$

does not exist However it is sometimes useful to as-

$$\int_C \mathbf{F} \cdot \mathbf{T}\, ds = \iint_S \mathrm{curl}\, \mathbf{F} \cdot \mathbf{n}\, d\sigma \quad \text{(Stokes)}$$

$$\iint_S \mathbf{F} \cdot \mathbf{n}\, d\sigma = \iiint_V \mathrm{div}\, \mathbf{F} \quad \text{(Gauss)}$$

In the form la of St kes F s a ve tor field S i a smooth surf having a pi cewi e mooth boundary c rve C d ected so th t S l es to the l ft of an ob- s rv p oceed ng al g C on the s de f S n which th n t n rmal cto n s cho n and T is the unit ta g nt vect r t C In t rms f the compon nts f F Stoke formula may be w itte

$$\int_C F_1\, dx + F_2\, dy + F\, d \; = \iint_S (F_3 \; - F_3)\, dy\, d \; + (F_1 - F_{3x})\, d\; dx + (F_2 - F_1)\, dx\, dy$$

wh re $F\,y = \partial F\,/\partial y$ and so on When the rf ce S l es in the xy pl ne thi quation r duces t Green form ula

$$\int_C F_1\, dx + F_2\, dy = \iint_S (F_{2x} - F\;)\, dx\, dy$$

The latt r i re dily pr ed for regions S of simpl shape a d from it St k s fo mula may b d duced

In th f m la of G u (als c lled the D ver ge c Theorem) V i a pace d m in bou ded by a mooth or p c wi m oth su fa e S and n is the e t r o rm l f S In term of th omp n nt of F Ga formula may b wr tte

$$\iint_S F_1\, dy\, d \; + F_2\, d\; dx + F_3\, d\; dy = \iiint (F \; + F_{2y} + F_3)$$

S e CALCULUS OF VECTORS

Functions defined by integrals Ment ha al eady bee m de of llipt fu ct o wh ch may be d fi ed th n e e fu cti s of ell pti ntegral Cert n d fin te integr l m y lso b u d to define mp rt nt on l m t ry fun ti s wh h cc fre- q ently n appl ati For example th gamma f nct on may be d f ned by

$$\Gamma(\;) = \int^\infty e^{-t} t^{\;-} \; dt$$

f r $\;> 0$ Th Be s l f t n f int gral o de m y be d fined by

$$J\,(\;) = \frac{1}{\pi} \int \cos(nt - \quad n\, t)\, dt$$

f r all l es of Th p operties f th fu ct o m be d d f m these xpr with th help f r u method f d nced aly s u h a th theory f f t n f mpl x a abl S e B EL FU CTION GAMMA FUNCTION

In g n ral $f(\;t)$ i n ntegrabl f t n f t $a \leqq t \leqq b$ f ch x th

$$g(\;) = \int^b f(\;t)\, dt$$

i a w ll-d fined fun t on of x Wh n u t ble c n d t a ti fied by the fun t on f the d i t ve $g'(\;)$ m y be calc l t d by the f rmula

$$g'(\;) = \int \frac{\partial}{\partial} f(\;t)\, dt$$

This process is called d fferentiati n under the in tegral sign It i valid in case f and $\partial f/\partial x$ are con tinu us in $(x\,t)$ f r $c \leqq x \leqq d$ $a \leqq t \leqq b$ where a and b are finite and ev n in more general ca es Howe er in the following simple example it g ves a wrong r sult

$$f(x\,t) = x\, e^{-\;\;t}$$

$$g(x) = \int^\infty f(\;t)\, dt$$

Then $\int_0^\infty \partial f/\partial x\, dt = \int_0^\infty e^{-} \; (3x^2 - 2tx^4)\, dt$

whi h i 0 when $x = 0$ although $g(x) = x$ for all x

Approximate and mechanical integration The d fin t on of the d fin t nteg al itself gi es a means of alculating ts value appro imately There re- main the questi n of a s itabl lection of the f ncti nal alu s $f(x\,)$ f r u e in th formula (1) It is usual to di ide the interval $[a\,b]$ into a numbe n f equal parts of l ngth h (Fig 2) If the p ints x_i a e taken at the m dp ints f the subinte al ne obta ns th m dp int f rm l

$$S = h \sum_{i=1} f[a + (\; - 1/2)h] \qquad (11)$$

Fo a c rve that i conc ve downward this gi es t l rge a v lu

An th r f m la alled the trap z idal rul i d r ed by calcul t n the are b l w a polygo in s r bed n the graph of $f(x)$ (Fig 3) Th s f r mula i

$$T = \frac{h}{2}\left[f(a) + f(b) + 2 \sum^{n-1} f(\; + ih)\right] \qquad (12)$$

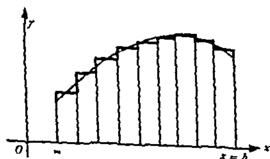


Fig 2

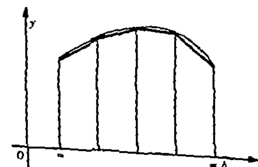


Fig 3

integrand of $L(C)$ is the length $|\mathbf{T}(u)|$ of this vector Thus one may write $ds = |\mathbf{T}(u)| du$ where s is the arc length measured from some convenient point on C

Let $A(x y)$ be a bounded continuous function de fined on a set containing a plane curve C having finite length Then A determines three functions of C called line integrals whose symbols and defini tions follow

$$\int_C A\,dx = \int^b A[f(u)\ g(u)]f\ (u)\,du$$

$$\int_C A\,dy = \int^b A[f(u)\ g(u)]g\ (u)\,du$$

$$\int_C A\,ds = \int^b A[f(u)\ g(u)]|T(u)|\,du$$

If $-C$ denotes the curve C traver ed in the opposite direction

$$\int_{-C} A\,dx = -\int_C A\,dx$$

$$\int_{-C} A\,dy = -\int_C A\,dy$$

$$\int_{-C} A\,ds = \int_C A\,ds$$

so that a reversal of the orientation of C changes the signs of the first two but not of the third of these functions

The extension of the preceding definitions to curves in 3 space is made in an obvious way An important application of line integrals is to express the work done by a force field on a moving particle Thus if a force field $\mathbf{F}(x y z)$ has components $F_1(x y z)$ $F_2(x y,z)$ and $F_3(x y z)$ in the directions of the x y and z axes then the work done by the field on a particle moving on a curve C is

$$W = \int_C F_1\,dx + F_2\,dy + F_3\,dz$$

When $\mathbf{T}$ is the tangent vector of C the work W can be expressed in terms of the dot product as

$$W = \int^b \mathbf{F}\ \ \mathbf{T}\,du$$

If $\mathbf{T}_1$ denotes the tangent vector of unit length

$$W = \int_C \mathbf{F}\ \ \mathbf{T}_1\,ds$$

To pa s from curves to surfaces replace the open interval $a < u < b$ by a bounded connected open set D in a ut plane which may be called the parameter plane The domain D can be restricted to be of sufficiently simple shape so that every function which is continuous and bounded in D is integrable over D as a multiple integral For example D may be the interior of a circle or of a rectangle Then a surface S in 3-space is defined by a triple

$$x = f(u\ t)$$
$$y = g(u\ t)$$
$$z = h(u\ t)$$

of functions continuous on D Such a surface is called smooth in case the functions f g and h ha e continuous first partial derivatives in D and the three Jacobians

$$J_1 = \frac{\partial(y\ \ )}{\partial(u\ v)} \qquad J_2 = \frac{\partial(\ \ x)}{\partial(u\ t)} \qquad J_3 = \frac{\partial(x,y)}{\partial(u\ t)}$$

are never simultaneously zero A smooth surface has at every point a nonzero normal vector $\mathbf{J}(u\,t)$ with components J_1 J J_3 and length $|\mathbf{J}|$

The area of a smooth surface S may be defined by the integral

$$\sigma(S) = \iint_D |\mathbf{J}(u\ t)|$$

and it is always finite when the vector $\mathbf{J}$ has bounded length

If $A(x y z)$ is a bounded continuous function de fined on a et containing a surface S with finite area four surface integrals can be defined as fol lows

$$\iint_S A\,dy\,d\ \ = \iint_D A[f(u\ t)\ g(u\ t)\ h(u\ t)]J_1(u\ t)$$

$$\iint_S A\,d\ \ dx = \iint_D A[f(u\ t)\ g(u\ t)\ h(u\ t)]J_2(u\ t) \tag{7}$$

$$\iint_S A\,dx\,dy = \iint_D A[f(u\ v)\ g(u\ t)\ h(u\ t)]J_3(u\ t)$$

$$\iint_S A\,d\sigma = \iint_D A[f(u\ t)\ g(u\ t)\ h(u\ t)]|\mathbf{J}(u\ t)|$$

If $\mathbf{F}(x y z)$ is a vector field with components F_1 F_2 F_3 and $\mathbf{n}$ denotes the unit vector normal to S with components $J_1/|\mathbf{J}|$ $J_2/|\mathbf{J}|$ $J_3/|\mathbf{J}|$ then a com bination

$$\iint_S F_1\,dy\,d\ \ + F_2\,d\ \ dx + F_3\,dx\,dy \tag{8}$$

of the first three kinds of urface integral may also be written in the form

$$\iint_S \mathbf{F}\ \ \mathbf{n}\,d\sigma \tag{9}$$

where $\mathbf{F}$ $\mathbf{n}$ is the dot product The expression (8) or (9) is referred to as the integral of the vector $\mathbf{F}$ over the side of the surface S to which the vector $\mathbf{n}$ points The integral over the opposite side of S is denoted by

$$\iint_S F_1\,d\ \ dy + F_2\,dx\,d\ \ + F_3\,dy\,dx \tag{10}$$

and $$\frac{\partial(\ \ y)}{\partial(u\ t)} = -J_1 \quad \text{and so on}$$

and (10) is the negative of (8) The last integral in (7) however is independent of a choice of side of the surface

The important formulas of Stokes and of Gau s are expressed in terms of line and surface integral and the triple or volume integral analogous to the double integral They are

int rval $[a\,b]$ has mea re zer in ca e it ca be n l ed in a seque e (fin t nfin te) of intervals, the um f wh e lengths i arbitrar ly mall Also a t p-fun t $f(x)$ s def d as ne whi h s con t nt on ea h i terval of a part t n f $[a\,b]$ as in Fig 4 The *Rieman int gral of a t p-funct on i* p es ble a fi te um The a bo ded fun t on $g(\ )$ i integrable in Lebesgue s en e n ca e t i th l m t of a un f rmly bounded qu nce of tep-funct o s $f(x)$ t e h po t of $[a\,b]$ except th n t S w th me s ze o nd by definition

$$\int^b g(x)\,dx = \lim \int^b f(x)\,dx \qquad (16)$$

I c se the t p-fu t n f i (16) a e replaced by Lebe gue-i t gr ble f t n form ng a un f rmly bo ded seq nce o ew fu cti n g ar bt ined

Th i t gr l of Lebesgue s also d fi ed for un bo ded f nct on b t the po t f nfin te d sco tin ty do not ne d to be nsidered ne by n For each f ct n $g(x)$ and ea h po it nt g r N let $g(\ )$ den te th les r of $g(x)$ a d N If ea h $g(\ )$ s Lebe gue t grabl in the al eady defi ed th numb r

$$\int^b g_N(\ )\,d \qquad (17)$$

f rm a o decr s g seq e ce nd so if the n m be (17) a bounded they t d to a finite limit, wh h s t k n a the v l e of

$$\int^b g(\ )\,dx$$

A arb t ry fu ct n $g(\ )$ i the d ff r f tw n n gat fu t ns

$$g(\ ) = \frac{|g(x)| + g(x)}{2}$$

$$g(\ ) = \frac{|g(x)| - g(\ )}{2}$$

d n may et

$$\int g(\ )\,d \qquad \int^b g(\ )\,dx - \int^b g^-(\ )\,dx$$

h ev bcth t m the r ght ha m a ing d g t th defin ti n j t gi en It s pr abl that th la f all fu t f wh h i tegral x t d ng t th d fi ti n ju t g e does fee f ha th p perty f mpl t nes with re- pect t th Cau hy o dit n (1) Th theo y of

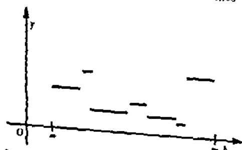


Fig 4

Lebesgue yield man other u eful results includ ing an xt nsi n of the fundame tal theorem of in tegral calculus One mpo t nt restriction on the lass of Lebe gue integrable functions which is im pl cit i the definiti n is th t wh n $g(x)$ s integra ble so is $|g(x)|$ This restrict on d e not hold for the imp ope integ al de cr bed in an ea lier p r gr ph

Th r ou metho l of defin ng Lebe gue inte- gral ar ext nsible also t functi n of several ar ables Th exten ion thr w l ght n the properties of mult ple Riemann integral and n the reduction of m ltipl integrals to repeated integrals

Other definitions of integration If $\alpha(x)$ is a fixed fu cti n defi ed on the int rval $[a\,b]$ the um (1) may b repl ced by

$$S = \sum_{i=1} f(\ )[\alpha(t_i) - \alpha(t_{i-1})]$$

Then f the limit I of S exi ts in thi ca e it is c lled the Stieltjes ntegral f f w th respect to α and i denoted by

$$\int^b f(x)\,d\alpha(x)$$

It has m y of the p operties of the R emann i te- gr l espe i lly in c e the funct on α n ndecr as- ng In addit n t may take pec al o nt of the alues f f at a fin te countable t of po t For x mpl if $\alpha(x) = c$ on $u_i < x < u_i$ whe e $u_0 <$ $> b$ $< u < b$ f r $i = 1$ $n - 1$ and if $f(x)$ is ont u us at each u_i then

$$\int^b f(\ )\,d\alpha(x) = \sum_{i=1}^{n-1} f(u_i)[\ _{i+1} - c\ ]$$

W th some estr cti to n ure con e g nc this may be xte ded to the ca e when α h s i fin tely many di co tinuit es The i a ariat n of the definit on of integral which g es the am re ult the R man i tegral but which may gi e diff r e t r ults fo th St ltjes i t gral

In the ase wh n α s n nd rea ng the St eltjes nt gr l has n xten n whi h is im la to th t of th Lebesgu int gr l and is called th Lebesgu St eltje nt gral

Other xt n n *of th Leb g e ntegr* l are the i t gral of D njoy They apply *to certain* functi ns f f r wh ch $|f|$ is n t integrable a d cl de th im pr per t grals but n t the Cau hy p n pal alue N me us othe type f integrals ha e b en defi ed In parti l r the nt gral of Lebesgue h be n xt nded to es when the nd p nde t a bl f es i u tabl pa e o i finit ly many d men s o wh n the f ct nal al es f f lie in u h a p Se CALCULU DIFFERE TIAL AND INTE C L FOURIER SE IES AND INTEGR LS SERIES

Bibl g aphy E. J B Gours t *A C u s in M th m t cal A alysis* 1917 L. M G a es *Theo y f F n t on f R l I a abl* 1956 P R Halm s *M u Th y* 19 0 G H Hardy *Int g t on of F n t ns f S gl I t abl* 2d ed., 1916 E. W

[L.M G]

It gives too mall a value for a curve that is concave downward

The error in the approximation may sometimes be reduced without increasing the number of subinter vals by use of the parabolic rule (Simpson s rule) To obtain the formula the subarcs of the graph of $f(x)$ are replaced by arcs of parabolas rather than by line segments Since three points determine a parabola (with vertical axis) the interval $[a\ b]$ is divided into an even number n of subintervals The area under the parabola passing through the points on the graph of $f(x)$ having abscissas

$$a + (2i - 2)h \qquad a + (2i - 1)h \qquad a + 2ih$$

is

$$\frac{h}{3}\left\{f[a + (2i - 2)h] + 4f[a + (2i - 1)h] + f(a + 2ih)\right\}$$

so the parabolic rule gives the approximation

$$P = \frac{h}{3}\left\{f(a) + f(b) + 2\sum_{i=1}^{\frac{n}{2}-1} f(a + 2ih) + 4\sum_{i=1}^{n/2} f[a + (2i - 1)h]\right\} \quad (13)$$

When a function $f(x)$ is given only by a table its integral is most simply computed by one of these formulas or a similar formula

When a function $f(x)$ is given by a graph me chanical means may be used to calculate associated areas One such means is the polar planimeter which registers on a rotating wheel the area enclosed by a closed curve around which a tracing point is pas ed The inte raph invented by Abdank Aba kanowicz is designed to draw the graph of an in definite integral of $f(x)$ when a tracing point is passed over the graph of $f(x)$ These simple devices were the forerunners of more complex machines de signed to solve differential equations such as the differential analyzer of Vannevar Bush For large cale computations involving formulas such as (11) (12) or (13) a digital computer may be preferred

Other methods of integration The method of differentiation under the integral sign is often con venient for the evaluation of definite integrals e en when other methods are available For example let

$$g(x) = \int_0 e^{x} \ dt = \frac{e \ - 1}{x}$$

Then $g\ (x) = \int_0 te \ \ dt = \frac{ae}{x} - \frac{e \ - 1}{x^2}$

If $$g(x) = \int_0 \frac{dt}{t^2 + x^2} = \frac{1}{x}\arctan\ (a/x)$$

$$g\ (x) = -2x\int_0 \frac{dt}{(t^2 + x^2)^2} = -\frac{1}{x^2}\arctan\ (a/x) - \frac{a}{x(a^2 + x^2)}$$

Another example in which the conditions for val d ity of the method till h ld though they are m re difficult to verify is given by

$$g(x) = \int_0^\infty e^{-\ t}\frac{\sin t}{t}\,dt \qquad 0 \leq x < \infty$$

Then $g'(x) = -\int_0^\infty e^{-\ t}\sin t\,dt = \frac{-1}{1 + x^2}$

as can be shown by integration by parts twice Hence $g(x) = -\arctan x + C$ and $C = \pi/2$ since

$$\lim_{\to\infty} g(x) = 0$$

In particular

$$g(0) = \int_0^\infty \frac{\sin t}{t}\,dt = \pi/2$$

In case an indefinite integral is not elementary but the integrand is representable by an infinite series the method of integrating term by term give a representation for the integral which may be u e for purposes of approximation For example

$$\mathrm{Si}\ (x) = \int_0 \frac{\sin t\,dt}{t} = \sum_0^\infty \frac{(-1)\ x^{2\ +1}}{(2n + 1)^2(2n)!}$$

Certain definite integrals may be readily evalu ated by means of contour integrals that is integral of analytic functions taken along curves in the com plex plane

Integral of Lebesgue In the study of the space of real functions defined for example on the inter val $a \leqq x \leqq b$ it is frequently useful to take

$$\int^b |f(x) - g(x)|\,dx \qquad (1$$

as the distance between the functions f and g Th distance already has a meaning when f and g ar Riemann integrable that is bounded and not to discontinuous in the sense specified for the Rieman integral There is no generally u eful extension the concept of integral to apply to all real function on $[a\ b]$ but it is desirable to extend it to apply the functions obtained from the continuous ones b certain limiting processes In particular it is de able to ha e correspond to each sequence $(f\ )$ functions satisfying the Cauchy condition for co vergence in terms of the distance (14) namely

$$\lim_{\substack{m\to\infty \\ n\to\infty}} \int^b |f_m(x) - f\ (x)|\,dx = 0 \qquad (1$$

a function g which is integrable (in the extende sense) and for which

$$\lim_{n\to\infty} \int^b |f\ (x) - g(x)|\,dx = 0$$

An e tended definiti n of integral having this pro erty was gi en l y H L Lebe gue in his thesi made obsolete many f the c mplicated exten io of the Riemann integral which had l een previou prop sed F llowi g Lel e g ie ario mathemat cians have pr po d other way f def ning the i tegral whi h ar eq i al nt t that of l el e gue

F Rie z d e l a def n ti n which can l e state q ite imply at lea t f r the ca e of a b nded fun tion $g(x)$ A a first definiti n a poi t set S in th

m l nocyt

Fg 2 A d d tc mel ocyt ot th d rmoep d m l l cto i s ct n f th h m k t h gh m g fi to (ph e< t t pt)

j nct elabo at ng th ir p gment n respon e t loc l nd ti n and thus cont buti g to the c lo f the k n a d its d r t s

M l ocyte A m t e de d ti m la oblast hi h has omme ed th y th f mela in p g m nt (Fig 2) i th mel n cyte It c nt s th e zyme tyr n wh h ataly e th x dat n f tyr dihyd oxyphenyl lan ne to mela n Th m la ocyt may be lled m l noph re but the l tt term doe t p ify that the ell ha it lf synth ed the p gm t wh ch t onta n M l n ph tes wh ch d ot h w tyr i e acti ty hi toch m c l test presumably ha e e gulfed mel n n g an les wh h we e produ ed n mel no ytes

I the h man ski mult bra hed mel nocytes at the d moepid mal jun ti n app ntl sert th r d dr ti p oc e a d tr fer pigment gr n les t t th ells f the tratum germ n t m (F g 2) Th p gme t i arr ed t wa d the k n u f ce by pr l f r t f th b sal ells but s grad ll l t du g ke at n zat o The of d m u t f p gm t njected t th b l ell thu det rm nes t l ge xt t th lo f th k n Th l ghte h m n ra es sh w r lati ly f w a t m la ocytes d espo d gly l ttl p gm t i th t t mg m ati um Fu thermo e th mo nt f p gm nt ynthes ed d depo ted e n e- po t loc l d t s i the p derm l b- trat m a ffected by h rm nes a d ther fa t rs Th d rke l t s ally p e t th pples, areola ternal g t l p e m a d gro n. Ult i l t r d t pp r tly t at th tyr e f m la ocytes l ad g t i c ea ed p gm t y thes nd d po i o Th g s th ppe ra ce f t n ng nd f eckl g S PIGMEN T TI

Development of the integument Th tw layer f th kin, pid rm and derm f rm n i t mate a soc at n b t th r r g n i d th p d rm dev l p g f om the embry n ectoderm a d th d rm f m th bj nt mesen hym Th ecto- d rmal ert g i at fi t a mpl c bo d l ep thelium By c ll divi ion an ut r l yer of flatte ed cells the p ride m is f rmed ell of the inner l yer remain uboid l s bsequ ntly th y divi le formi g the distin ti e t ata f skin a d the pri mordi f the va ous p dermal d ivati es s ch a h r glands nd similar stru t r s In mammals developing ha r penet ate the epide mi nd l ft fi th tough pe derm a c ntinuo s ep trichial sheet

The de m s r co ium tig n t s f om mesen chyme subjacent to the ep d rm s This arises chiefly from the lateral heets of somat me oderm in h gher ert b ates although tl e mesoderm l som t may contr bute cell t the d rmi of the back skin In the head region neural rest cells may pa ticipate in fo m tion of the de m s

The p ospect e derm at fi st compri es scat te ed t llat c ll epa ated by embry n c r n d s b tan e and s not eadily d stingu shable f m tiss es dest ed to f m the s bc t neous tis ue muscle a d bone Sub eque tly howeve a com pact l yer f me enchyme of th fibr bl stic type d ffe entiates immed atelv beneath the ep derm s p oducing fi st a feltwork of wh te ollage ou fibers and lat na tomos ng llow fibers of el s- t n Bl d ve l d rve n ad the co ium f om bel w gla ds a d othe ep dermal d i ati es g ow i to t fr m tl v rly ng epide mis

Inte ti ns betwe n todermal nd mes derm l comp nents of the nt gument qu ite to the diff rent ti of th kin and its de i ati es In th hi k embryo fo example the pr pectiv de m s is pp rently ncapable of o g nizing either a typ al cori m o th derm l papill e of the f ather germ in the b nc of th e tode m Also n th h ck egi nal diff ren es in the cha te i t s of the epid rmal deri t a e cont lled l y fact rs f tl e p specti de mi

Epidermal derivatives These st ctur l mod fic t ns f the p d rmi u h a h s s ales f thers and glands wh h usually ha e a value n adapting the rg n m t its p rticul mode of life E ag t o s f the pid rmi f rm les f ath rs ha ib ae h f claw a d h n The us lly d lop i latio t n nderly i g mesodermal r wh h pro id s th tial tim l t the ep dermal utgr wth I v g at n f th p derm s f rm a a ty of gla ds wh ch ef ec t ng p rti s a e mb dded in the de m *See* GLA D

Dermal derivatives Structu al m dific t ons of the d rm e hi fly th e ntr but g t the pro- tect e armo nd sk l tal parts S al of ha ks fi h nd me eptiles are d ri ed f m the d rm s The memb ane bones not bly of the f c and c a n l ult m n n de ed i be f d rmal or gin Vascula modifi at n f the derm g e r e t mbe f tructures u h s th omb d wattl b ds and the sexual k f e ta n apes wh h are po ibly f val n xual ec gn t n S PROTECTIVE COLORATION SCALE (ZOOLOGY)

[J W S]

Hobson *Theory of Functions of a Real Variable* 2d ed 1927 B O Peirce *A Short Table of Integrals* 3d ed 1929

Integument

The skin or outer covering of the body together with its various derivatives such as hair glands scales It consists basically of two tissues an outer epidermis and an inner corium or *dermis* The lower layer of the dermis in man and many other animals rests on a fatty subcutaneous tissue or hypodermis which smooths out the contours of the underlying bone and muscle The skin with its derivatives and associated hypodermis comprises an organ system which protects the underlying tissues and according to the mode of life of the animal may serve important functions in respiration excretion water balance protective coloration sexual recognition and others

Epidermis This is the outer portion of the skin It is a many layered epithelium comprising characteristically two distinctive strata of cells the stratum germinativum or basal layer which rests on the dermis and the outer stratum corneum In man the thick skin of the palms and soles shows two intermediate layers the stratum granulosum and the stratum lucidum interposed between the stratum germinativum and stratum corneum (Fig 1)

Stratum germinativum The innermost stratum of the epidermis is the germinativum or Malpighian layer It rests on the dermis and proliferates cells which are added continuously to the outer layers Its basal cells are cylindrical and oriented perpendicularly to the surface of the skin In most vertebrates daughter cells of this layer show a gradual transition to the more flattened cells of the stratum corneum In mammals however there is a striking contrast between the live cells of the stratum germinativum and the flattened cornified cells of the outermost layers of the skin

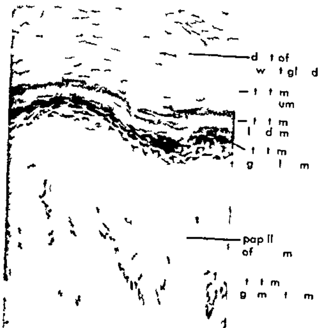


Fig 1 The char cte st c st t of th k k n of the human fnge as ee f cross sect on at h gh mag f c t o (F m J F N n d z and W F W dl T t book of H tology McGraw H ll 1949)

Stratum corneum This the outer layer of flattened keratinized cells of the epidermis is particularly well developed in the higher vertebrates It is contributed by cells proliferated from the stratum germinativum As the cells move upward they become flattened and their contents transform almost entirely into keratin The outer layers of keratinized epithelium are progressively cast off as new cells arrive from below

Dermis The deeper layer of the skin is the dermis corium or cutis a dense connective tissue richly supplied with blood vessels nerves and associated sensory organs (*see* SENSE ORGAN) In it are embedded the glands of the skin and other epidermal derivatives such as hairs and feathers The upper surface of the dermis the soft papillary layer is in contact with the stratum germinativum of the epidermis and is thrown into folds and projections interdigitating with local thickenings of the stratum germinativum The papillary layer grades into the denser reticular layer below The latter contains fewer cells and comprises a dense feltwork of collagenous fibers variously oriented but chiefly parallel to the skin surface Elastic fibers are less numerous forming a looser network which is most prominent about the hair follicles and sweat and sebaceous glands Collagenous and elastic fibers of the dermis are continuous with the fatty subcutaneous tissue below *See* FEATHER (BIRD) HAIR

Pigment cells The color of the skin and its derivatives is due largely to the presence of distinctive pigment forming cells or chromatophores in the epidermis and dermis These cells are variously designated according to the color and chemical characteristics of their pigments Chief among them are melanocytes containing granules of melanoprotein or melanin an oxidation product of the amino acid tyrosine which in different cells may range in color from black through brown red and yellow guanophores or iridiocytes filled with iridescent crystals of guanin and a variety of lipophores containing yellow red and orange types of pigment Melanin pigments are chiefly responsible for the color of human skin although carotene and hemoglobin contribute notably *See* CHROMATOPHORE

Melanoblast A prospective melanin producing cell is the melanoblast Originating from the neural crest the melanoblasts migrate to all regions of the body During their dispersal they are indistinguishable from the cells with which they are associated but their presence may be detected by means of proper transplantation or tissue culture experiments In most vertebrates they assume positions in the dermis and at the derm epidermal

S e t glands unl ke h r f ll cle w ll fo m a ew
ı art

Th vels t on dee a tlers ı an excepti n to
th r le that the full thickne f mammal an k n
can t be reg nerated Thı layer of typical hair
bea g kin pe l ff bef e th antlers are shed
b t r g n rates with the new set of antl rs

[R F BI]

B bl og aphy L. B Arey *De elopm tal An t omy* 5th ed 194 W D M El y and H B Cla (ed) *Chemical Basıs of Devel pme t* 1958 W M ntagna *The St u tu e a d Fu ction of Sk* 1956 S Rothma *Physiology nd B ochem try of th Skin* 19 4

Integumentary patterns

These e mpr ll th featu es f th kin nd ıts appe dag th t ar ar anged ı des g both ı m n a d th r an m l Examples re ale h a d f th r lo atı n and ep dermal ridg s f th fi ge p lms nd feet. In t omm n usag th t rm ppl es t the onfiguratı n f ep d rm l r dge e ll t ely med d rmatoglyph c Derma t glyph ar chara t tı of p ım t s

The up fi l r dges a e a c ated with a spe fi ınn r rganızat f k n Sk c mp ed of t h f l e ep de m on th out d and the dermı u d rlying ıt (Fig 1) Tl e two l y r re m tı d l y peg f d rmı a d uble r w of p g rrespo d g t a h ıdg the e p g c ord ngly f m a p tt nı g l k th t f th dge

Ridge patterns The patte n g of dg n lud ng th t f the p dermal-dermal m rtı ng ıs d t m ed d ng the th rd nd f rth f tal m th All h a te ı t f ngl dg nd f th ır al g m t th l t rm ed d fin tı ly R dg al g m t refl t d t ns f tre s g th f th h d d foot at th c ıt al p ıod f dg d ff entı t n A mp rt nt el m nt ı th p od t f localized p tt ns f r example

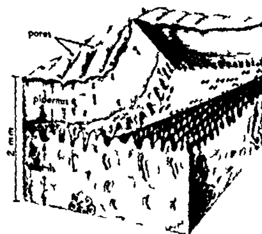
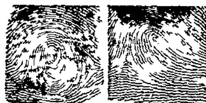


Fig 1 Structu f ridg d kı (F m H C mm d C Mdl F ng P ft P lm d Sole M G w H ll 1943)

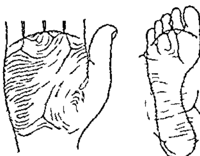
on the terminal segment of each d gıt ıs the de el opment ın the fetus of a erıes of ele atıons the lar pad

Volar pads The pad are hom logs of th pr m ne t pad on the paws of me mammals but n prımate th y attaın little elevation and oon tend to subside (F g 2) Th p ls are dı po ed ın a con ı te t t pographic plan Localized patterns ha e the same plac ment becau e growth of the



( ) (b)

Fg 2 F ge p t (a) Who l (b) l p (F m H C mm d C M dl F g P t P lm d Sol M G w H ll 1943)



Fg 3 D m t glyph c of p lm d sol (F m H C mm d C M dl F g P f P lm a d S l M G w H ll 1943)

pad the d termı r f th specifi l al p ttern When a pad ha ub d d before ridges ar f med ıts ar a doe n t p e ent a locali ed pattern and the ridge f llow es tı lly stra ght parall l u V r at ons co t u s of the pads a e ac c mp nied by wide r at on ın th des gns f rm d by th dg rlying t.

Pattern variability V rial l ty of patt rn g ıs a m ı r featu of d rmat gl phı s and the ba s for var appl catı ns (F g 3) In personal ıd ntifi cat pr ts cu toma ly of fi ger are cl s fied f r fil ng ın corda wıth a iables f patt rn typ and co t of r dges Sy temat c fil ng mak s t p ible t l c te r adily nd cor pa e the s ts f print rrespond g ın l fic t on to a set f wh h an d t fication s s ght In anth opolog cal and m d l ın e t g t ns g ups f nd ıd al r c mpared ta t ally ın f n to the oc r re ce f thes arıable Deductı may be drawn ın da ce w th l k e r l k ness ın the d rectı of varı t n A few examples are cıt d T d f ınherıta ce h e be n dem nstrated n f m ly gr up and mp r on f the two types

ULTRASTRUCTURE OF SKIN

This aspect concerns details of submicroscopic structures of cellular morphology too small to be een with a light microscope The electron micro scope affording magnifications of 2000–200 000 and ancillary techniques must be employed in this study

Epidermal cell cytoplasm contains in addition to the usual components narrow (about 50 A or 0 005 μ wide) filaments which appear to transform in the stratum granulosum into the solid keratin of the cornified layers Grouping of these filaments or tonofilaments into tonofibrils increases with dis tance from the basement membrane They are most prominent in thick skins and least in thin skins Tonofilaments made up of prekeratin protein re main intracytoplasmic even within the intracellular bridges or Bizzozero nodules They terminate at electron dense areas subjacent to each cell mem brane The two cell membranes within a bridge are separated by a 300 A wide band of amorphous ma terial which changes in the stratum lucidum or lower stratum corneum and is removed as cells des quamate (Fig 3)

The ba ement membrane is a 350 A thick sheet of amorphous material and associated filaments which completely separates the epidermis from the dermis or corium Collagen fibrils each displaying a characteristic macromolecular striation are found individually each 300–800 A wide or grouped i fibers in all intercellular spaces of the corium See ANGSTROM HISTOLOGY SKIN see also MICRO-SCOPE ELECTRON [C.C.S.]

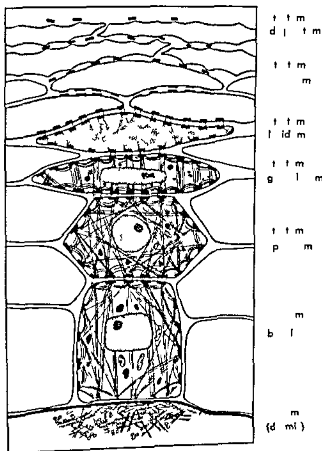


Fig 3 Schem t c draw ng of the m phol g cal d f fe e t at on of the ep de m s

REGENERATION

The skin of man and other mammals has a highly developed capacity for regeneration The epidermis, or outer layer is continuously replacing itself through proliferation of its lowermo t cells as the cornified epidermal cells from its surface are lo t through normal wear The epidermis of the ole of a rat s foot for instance undergoes complete re-placement in about 3 weeks

Cutaneous wounds Healing of cutaneous wounds is a regenerative process If a mall patch of epidermis is scraped off and a few cattered fragments of its lowermost layer are left epiderm will regenerate rapidly by proliferation of the e re maining cells If no epidermal fragments are left, a new layer of epidermis will appear over the de nuded area as a result of an inward movement of epidermis from the wound margins Multiplication of the cells present in the new epidermis restores its thickness to normal

Fingerprints a system of ridgelike elevations of the epidermis are regenerated accurately ever after complete destruction of the epidermi pro vided that the underlying tissue is undamaged See FINGERPRINT

Deep wounds The capacity of the dermis th tough fibrous inner layer of the skin to regenerat is unfortunately incomplete Lost superficial level of the dermis are replaced by the activity of con nective tissue cells which lay down new collage fibers If the full thickness of the dermis i exci e or destroyed as in third degree burns it is not re generated All that the body can do is to produc a thick layer of fibrous tissue which eventually be comes covered by epidermis The final product i scar tissue and is quite unlike normal skin Scar ti sue lacks re ilience and mobility the orientation o its fibers is abnormal and the epidermis never be comes firmly united to it In the early tages o maturation scar tissue undergoes contracture s that the margins of small wounds are brought to gether and only small cars result Skin grafting i the only sati factory treatment for extensive lo or destruction of the full thickness of the skin i man Skin is an ea y tissue to graft l ecau e of it proliferati e capacity however the graft take permanently only if the skin donor is the patien him elf or hi identical twin

Hair Regeneration of hair depends on regenera tion of hair follicles Hair follicles are specialize projections of the epidermis int the dermi The will regenerate completely provided that a smal ba al fragment remains undamaged Thi fragmen mu t in lude the papilla a dermal structure lyin at the l ottom of the f llicle Only in a few animal su h a the rabl it under special experimental c n ditions doe scar ti sue e er gi ri e to new hairs

tests lso r flect the al e wh h th pe son pl ces nt llectu l act ty d hi gen al n ed t a hie e or e el (*see* MOTIVATION)

Desp t the omple ty of the ph ome the ncept of gen al intell genc d th tand d ized tech iq es f t me reme t tin e to be h ghly u f l s h pract al probl m as th d agno i f me tal d fi e cy th pred ct o f academ c p t tial and s cess a d th elect of perso el n i d stry d th mil t ry rvi e *S e* PSYCHOLOGY PHYSIOLOGICAL AND EXPERIMENTAL. [U B]

B bl g phy J B Mi er *I tell ge the U t d St tes* 1957 J P ag t *Th Psychology of Int ll g e* 1950

Intercommunicating system

A teleph e y tem p d ng direct omm t b twee t l ph e n the same pr m s of t sh rte ed to intercom S ch y tems e f tw g eral typ s (1) tho t l g regular tel ph s assoc ted with th t wide t l ph e tw k d (2) local y t ms ot asso ted with the nat on w d teleph twork B th type ra ge f m s mpl t c mpl in scop

Telephone utilizing systems Int mmun t i g sy tem t l zi g i trume ts a c ted w th th nat n w de tel phon tw k lly empl y t l pho eq pped with a n mber f key th t a p rt c l r t l ph can be con ted the t a y of er l t l-offi li (or PBX e te) or t an i ter m l Sy t ms mploy i g h key-eq pped t leph t g th with any r l y l mp d ther related app rat s nd w g e alled k y t l ph e sy t m or n som f m k y eq pm t Th y r furn hed in wid r ty f embod m t F ample the k y may f m i t gr l p t f th t leph ne set r may be p at ly m ted S gnal lamps wh h fl h t i d c te i com ng c lls, l ght st d ily d g t d w k wh l a l is be g h ld m y me a u fo m In ome key



Fig 1 Si b k y t l phon (B ll T l ph L b or ories)

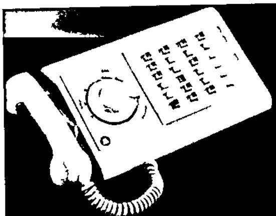


Fig 2 Th rty b tt k y t t (B ll T l ph L b r)

t leph e (F gs 1 a d 2) the k y b ttons are m d f tra pa e t plast d ar ll minat d f om b th th l serv g as visual signals *Se* TELEPHONE TELEPHONE PRIVATE BRANCH EXCHANGE (PBX)

Th l rger key eq pment ofte t ke the fo m of key t rr t wh h are wood m t l bo es r ng d f de k top mou t g (e F g 2) Some t m the keys l mp nd design tion ar ar ra ged a m dula bas so th t additi al nits n b dd d lat f de red Oth key eq ipme ts e d gn d f hor nt l i t llat on an p n ing a t ble t p

Optional features Key equipments oft n provide for w de iety f pt nal fe tur The m re mp rta t f th e ar d cu d he e

H ld O e k y wh n pe ted m m nt ily pla s h ld b idge (ually r st) cr s the li e th t the u e m y temp ar ly tr nsf h s tel ph e set to n i te com li e r t a ther en tr l ffi e li PBX e te n w th ut c u g d co e ti n f the igi al call He can the r t n to the origi l ll by r p rat ng the r gi n l li key

I t com ignal g By d li g a on r two-d g t cod by pe at ng parti ul r k y par t l r teleph e be ng

C fe c ll g By m lta u ly ope t ng ev al s gn l g k y g o p of t leph can b r ng a d ll who a sw r can e e

P es t f e c c ll g By diali g a part cu l one- or two-d g t de p earr ng d gr up of telepho e c n b r ng multa eo ly nd ll wh a swe a c n e se

C mp n Whe ther t leph e erved by the am k y eq pm nt i dialed d f d bu y th c lle by n t h ng g up amp n the con nect As oo as the lled telepho e f e it w ll be ru g aut m tically d the wait g caller will b c n t d he d f a y ther wh m y ha e tr ed to r ach th t p rt cul r t l pho e i th m nt m

Add-o If all s rec d f om a c t al-offi e l e r PBX e t n i n (that is not ia nterc m l) nd the lled party w h s t add oth r t le

of twins fraternal (two egg) and identical (one egg) Dermatoglyphics thus are useful in diagnosing the types of twins and in analyzing cases of questioned paternity Among different racial groups the similar or discrepant trends of variation have been used to analyze racial affinities Trends of variation are unlike in right and left hands and the fact that they differ in accordance with functional handedness indicates an inborn predisposition of handedness *See* EPIDERMAL RIDGES FINGERPRINT HUMAN GENETICS SKIN [H CU]

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Intelligence

Defined as the ability to learn to carry on abstract thinking or to adapt to the environment

Intelligence tests However intelligence is defined the ability is almost universally measured by adaptations of the testing method invented by the French psychologist Alfred Binet in 1904 In this method the subject is given a variety of tasks involving such activities as manipulation of symbols the perception of analogies and complex relations the comprehension of causal connections and the solution of verbal and mathematical problems The technique assumes a common background of experience with the mental operations involved so that differences in performance presumably reflect variations in ability rather than in trained achievement but in actual practice the distinction is difficult to maintain Thus intelligence test scores show substantial relationships with highest grade reached in school and with measures of academic achievement Although undoubtedly contaminated by effects of training and experience the intelligence test nevertheless provides a better index of potential ability than any other method presently known to science

Intelligence quotient The results of intelligence tests are ordinarily expressed by comparing the per on s score with the a erage for his age group The measure most commonly employed for this purpose especially with children is the intelligence quotient or IQ This is a ratio multiplied by 100 to avoid decimals of the child s mental age that is the average age at which children achieve the score obtained by the subject and the child s actual or chronological age Intelligence quotients of 60 or below are usually interpreted as indicating mental deficiency while those of 120 or above as reflecting superior mental ability (*see* MENTAL DEFICIENCY)

Viewed developmentally intellectual capacity appears to grow at a declining rate until about fifteen years of age Thereafter although the person may obviously increase his store of knowledge and thereby his skill in the solution of problems in particular areas there seems to be no further gain in absolute reasoning power or capacity to perceive complex relations

Components of intelligence The nature of intelligence has been investigated primarily through statistical studies of the relationships between scores in various kinds of mental task On the basis of such work some investigators following the lead of the English psychologist C Spearman conclude that intelligence is best described as a single general factor which enters in greater or lesser degree into all mental activities A contrasting view championed by the American psychologist L L Thurstone posits a series of six primary factors labeled number verbal pace word fluency reasoning and rote memory The six factors nevertheless show appreciable relations with one another especially at the younger age levels

Since World War II research on the nature of intelligence has shifted from a statistical analysis of content toward the experimental study of cognitive processes such as innovation concept formation and the perception of causality

Bases of intelligence Little is known regarding the physiological and neurological foundations of intelligence Comparative studies of different animal species suggest a gross relationship bet een ability in problem solving and the ize of the cerebral cortex the outer layer of gray matter of the brain but this correlation does not appear to hold within species Injury of cortical ti sue in both animals and men produces a loss in mental function Mental impairment may also be brought about through drugs endocrine malfunction low oxygen supply to the brain or even prolonged isolation from external stimuli for example through immersion of the body for several hours in water at body temperature in a soundproof and lightproof chamber

Attempts to identify the relative contribution and interaction of genetic and environmental factors in the development of intelligence have been made with both animal and human subjects At the human level the classic studies of H H Newman and his colleagues indicate that identical twins reared apart show differences in IQ almost twice tho e obtained for identical twins reared together In the 1950s a growing body of research evidence points to the importance of early experience both before and after birth in the development of intelligence The nature of the intervening mechanisms is not yet known but climatic endocrine and nutritional factors appear to be most relevant in the prenatal period whereas influences associated with prematurity and stimulus deprivation seem most powerful at birth and immediately after *See* BEHAVIOR AND HEREDITY LEARNING THEORIES

At later age le els greater attention is being paid to the role of social and motivational factors It is becoming increasingly clear for example that mental de elopment as measured by intelligence tests varie markedly as a function of the family s cultural background and socioeconomic p sition Nor does it appear likely that the so-called culture free te ts will l e entirely ex mpt fr m thi effect Rather the evidence uggest that along with na ti e al il ty and the effects of intelligence

tests also reflect the alue wh ch the p rs places on i tell ctual act vity and hi gene al need to ach ev o e el (s e MOTIVATION)

Desp te the c mplexity f the phenom no the c c pt of g e al i t ll g nce and th tand rd ized tech iq es for ts m as eme t conti ue to be h ghly useful n uch practic l probl m a the d agn of mental defici ncy the pred cti n of adem c pot ntial nd s ccess and the lecti n f pe son el n i dustry nd the m l tary servi es S e PSYCHOLOGY PHYSIOLOGICAL AND EXPERIMENTAL. [U B]

B bl g aphy J B M n r *I tell g nce i th U u d States* 1957 J Piaget, *The Fsych logy f Int ll g ce* 1950

Intercommunicating system

A tel pho e sy tem p o idi g d r ct mmun ca t n between tel phone n the s me p em es of t n short ned t inte c m S ch y tem a e of tw g ne al types (1) tho e util zing egul r telephones soc ted with the nat on wide teleph n netw k and (2) lo al ystem ot a soc ated with th at o wide t l pho e etw rk Both types ra ge f om mple t c mplex n e pe

Telephone utilizing systems Int rcommunic t ng y t m til zing in trume t a sociat d with th t n w d telephone etw rk usually mpl y t leph es equ pp d with n mber of key th t a p tt l t leph ne b c n t d e ther t y o e f l e tr l-offic l ne (r PBX ex t n o) or to a inte om l e Sy t m employ i g h key-eq ipped teleph e together with any elay lamp and th r elated pp r tu nd wi ng re alled k y t lepho e y t m or in som f rms key qu pm ts Th y a e furn hed in wid ar ty f mbodiment Fo ex mple the k y may f rm a int g al part f the tel ph ne t r m y be p ately m u ted Sign l lamp h h fl h t d at in m g ll l ght stead l d ring e n ati and wi k whil li e e g h ld may a me a i f rm l ome key



Fig 1 Si -button key t l phon (B ll T l ph e L b or orie)

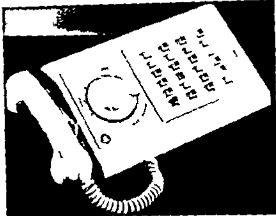


Fig 2 Thirty b tto key t t (B ll T l ph e Lab t)

t lepho e (F 1 and 2) th k y butt ns are m de f tran par nt pl st c and a e illumin ted f om ben ath thus al o rving as v ual ignals S e TELEPHONE TELEPHONE PRIVATE BRANCH EX CHA GE (PBX)

Th l rg r key eq pm nts oft n take the f rm of k y turrets which are wood or metal b xe ar ranged f d k top mount ng (see F g 2) Some t m s the k y lamps nd d s gnations a e ar r nged on a modula b is th t dditional unit c be added lat r if d ired Othe key equipment r de ig ed f r h r ontal in tallat on in a open g in t bl top

Optional features Key eq ipments often pro ide f r a wide variety of pt n l f atures Th m re imp rt t f the are d cu ed he e

Hold One key hen perated momenta ly pl es a h ld bridge (usually a r sisto) cro s the l e so th t the us r may tempor rily t an fer h s tel ph e set t an nte com line o to a the ce tral-offi e li e or PBX xten ion without cau i g d nnecti n of the rig nal call He c n then re turn to the rig nal ll by r per t ng th origi nal line key

Inte om signal g By d al ng a o e- o two-digit c de r by per ting a part c lar key p t l r teleph ne ca be ung

C nfe e c c ll ng By imultaneou ly perating e e al sign l g keys a g oup f telepho es can be r ng nd ll who a swe con s

Pres t co fe calli g By dial ng a p rt lar o e two-d g t ode a p earranged g up of teleph e can be g im lt n ly and all who w r can c r e

C mp-o Wh n anothe tel phone erved by th ame k y qu pm nt is dialed nd f und busy the calle by not h ng g up amp on" the con ti n As soon a th c lled telephone i f ee t w ll be ru g automatically and the wait ng ll w ll be connected ahead of a y th who m h t ied to e ch th t p rticular tel ph n n th m a t m

Add-o If a c ll is rece ed f om c ntral-offi l e o PBX te n (that s n i y a an int com l) d th all d party w h to add ther t l

phones served by the same key equipment to the connection he may do so by operating keys provided for the purpose If he so desires he can then drop off the connection leaving the other party or parties connected

Hands free talking A microphone a small loud speaker means for amplification a suitable transmission network to prevent howling a volume control and two control buttons (ON and OFF) permit two way conversation without lifting the regular handset from its cradle (see Fig 3) The handset can however be used in the usual way when desired This arrangement can be associated with key telephones as well as with ordinary telephones

Privacy Various arrangements are available whereby certain telephones which normally have access to a particular line can be denied access when privacy is desired during a particular conversation One such arrangement utilizes one of the switchhook plungers which is so designed that it can be pulled upward above its normal position The feature is automatically canceled when the handset is replaced on its cradle

Executive access In ome key equipments one or more telephones can be arranged so that an executive for example can obtain access to his subordinates telephones whether or not they are busy

With such a large number of optional features available the nece sary relay equipment to perform the various functions is usually designed on a building l lock basis for flexibility

Particular applications Intercommunicating systems have also been developed to meet the need of particular applications such as residences and farms



Fig 3 Key telephone arranged for ho ds-f e t lk
[illegible] es)

Residence intercommunicating systems may include such features as local signaling and talking hands free talking and door answering The latter permits residents to converse with anyone who rings the doorbell from any telephone in the house

Farm intercommunicating sy tems are de igned to provide facilities for communicating bet een residence and barns including the ability to an wer or originate calls via the telephone central office. At least one telephone is normally equipped for hands free operation and at lea t one loud ringing bell or its equivalent is usually provided for out door coverage in addition to the regular bells on each telephone

Local systems Local intercommunicating systems not associated with the nation wide telephone network vary widely in ize complexity and type of operation In various forms they u e m t of the other features of telephone utilizing sy tems although with different technical characteri tics

Many such sy tems contain high gain amplifiers and permit voice paging l y direct operation of loudspeakers at subordinate tations under control of a press to talk lever at a ma ter tation Usually these loudspeakers serve al o a dynamic microphones for speech in the oppo ite directi n Some systems make use of ordinary lighting circuits for voice transmis ion by using carrier principle to avoid the need for interstation cabling [R F D]

Interface of phases

The boundary between any two pha es Among the three pha es gas liquid and solid five types of interface are possil le gas liquid ga olid liquid liquid liquid solid and solid solid The abrupt *tran itions from one phase to another* at these boundaries even though sul ject to the kinetic ef fects of molecular motion is statistically a urface only 1 or 2 molecule thick

A unique property of the urfaces of the phases that adjoin at an interface i the surface energy whi h is the re ult of unl alanced molecular field exi ting at the surface of the two pha e Within the l ulk of a given pha e the intermolecular f rces are uniform l ecause each m lecule enjoy a stati tically homogeneous field produced l y neighboring m lecule of the same sul tance Molecule in the surface of a pha e howe er are l ounded on one ide by an entirely different envir nment with the result that there are intermolecular f rce that then tend to pull the e surface m lecule to ard the l ulk of the pha e A drop of water a a re ult tends to a ume a pherical hape in order t reduce the surface area of th dr plet t a minim m

Surface energy *At an interface there* will be a difference in tl e tenden ie f r each pha e t at tract it own mol ule C n eq ently there i al w y a minim im in the fre energy of the surfaces at an interface tl e n t amount f wl i h i called tl e i t rfa ial energy At tl wat r air interfa e f r example th lifferen in m lec ılar fel l in tl e wat r an l air i rf r tl e i t facial energy of 72 erg / 1 s

Th nt rfaci l n rgy betw en the tw l quid benzene and water i 35 ergs/ m and between ethyl ether and me cury i 379 erg / m The e nterfac al en rgies a l o expre ed as su fa e ten n nu t of dynes p entimeter

The u face ergy at an nt rf c may be alt red by the add t o of olutes that m grate t the r f e a d modify the m le lar f ces the e th f energy may be ha ged by c n rt ng the pl nar nterfacial boundary to a curv d urfa S e ADSO PTION SURFACE ACTIVE AGENT Both the theor t c l and p a tic l mpl cation of tl s ha g i u f c e ergy e embod d n the Kel in equ t o

$$\ln \frac{P}{P_0} = \frac{Mγ}{RTρr}$$

wh re P P is the r ti of the apo p e s re of a l qu d dr pl t with d am t r to the po pres u e f th pu e l q id n bulk ρ the d ns ty γ th r f c en gy and M tl m le la w ght Th the m ll r th dr plet the g e ter the rel t e po p es r nd a n eq e mall dr plet f l q id e ap r t mo e r p dly tha la g r nes The rfa nergy f l d i also funct on of the z a d the K l i equat can b mod fied to descr be the g at lub l ty f mall part les mp red t th t of la g r p rticle of th me sol d

Contact angle At l q id sol d t fac wh e it fl f the tw pha es i s ally termed w it g t al f t c lled the t ct angl is n led A d p f w t pl ed n a paraffin fa f e mpl et n gl bul hape whe ea th sam d p f wat pl ed a lean gl ur fa p d o t t a th n laye I th first in t th t t ngl s pr cti ally 180 and n th sec d i t n t p ti ally 0 Th t dy f t t ngl e al the t pl y f nte fa al en gies at th bo d r es Th ll t t n i sch m t r p es nt t f th s sect f a dr p f l q d a l d There a e ol d l qu d sol d ga and l q d ga nt fa that me t h so t O Th f es abo t O sh t d te m th eq il l ta t a gl r l ted t h th

$$γ = γ + γ \quad θ$$

h th γ t rm p ese t f e n rg e at the t l es nd $θ$ the t t a gl S n e nly $γ_{LG}$ a l $θ$ a be m a ed r d ly the t rm adhe n ten d fi ed

$$γ \quad \cos θ = γ_{SG} - γ_{SL} = \text{dh} \quad \text{n ten io}$$

Adhes ten n wh h tl f nergy f t t g is f r t l mpo t n d t rg n y d s hes l r d ng p ocesses

Th m m t f s t f l rg es mad d ectly ly po l qu l ga d l q d l q d t fa es In m i g th l qu d g nt fa i l en g (rf ten) th method f r ll ry se d p w ght pe d t d p b l bl p es

essil drops Du Nu y ring v brating jets an l ultra nic a tion a e among th used There i small b t app ec able temp rat r ffe t upon s r fa e t n n and this property i u ed to d termine small d fferences in th urf e t n on of a l quid by plac ng the two ends f a liquid column in a

$γ_{LG}$ g

$γ_{SG}$ θ $γ_{SL}$ l q d

O

sol d

Th t ct angl $θ$ t th t rf f th ph

ap ll ry tube wh e tw end ar at diff r nt t m pe at re The determ nat on of i t rfa ial ener g e t oth r types of nterfac s can be nfe r d only by nd ect m thods *See* EQUILIBRIUM PHASE FLOTATION FOAM FREE ENERGY SURFACE TEN SION [W H.S]

B bli g aphy N K Adam *The Phy i s and Ch m stry f Surf ces* 3d ed 1941

Interference electrical

Any de ired l tr c l en rgy that t nd to n t rfe e with the rec pt on of des ed i nals It m y b a man made gn l g e ated by nea by elec t ic mot rs aut m t e gn t n y tems rad o t an mitt s imp op rly perat ng tele i i n i r r wid ar ety of othe impr p rly pe ati g le tr c devi es Th i terfe nce gnal ith r may be r di t d tl gh spa as unguided lectr ma net c wa r may tr vel al ng pow r li gu ded ad ati Interfe ence may lso b au d by tm pheric pl nom na u h as light n ng Su f nat ral distu ban e a e m t mes t rr ed fe (e NOISE ELECTRICAL) Int fer i g ig als e som time g n r ted tent nally by po f l tran mitters f r th p rp e of jam m ng c mmuni t o and rada yst ms

Man mad interfer e be t pp e sed t its sou c by ch me n a m n mizing park ng co necti g ap tors a os pa ki g co ta ts hi ld i g th eq pment th m tal en los and u i g ch k coils r filt s th t pre ent interf ring g nal f om enter g p we lines *S e* FILTER, ELEC TRIC SHIELDI G ELECTRICAL. [J IR]

Interference filter optical

A opt al filter in wh h the w l ngtl that a e n t t an mitted r rem ed by nte f re e phe n mena r th than by ab orpt n o tt ri g (I TERFERENCE OF WAVES) In addit n to be g able t d pl t m st of the pect al characte istics of absorpt c l r filt th se dev ce c n be m d t tra m t a very nar w band of wa e le gths They c n th s be used a m ochr m tors t e m e a rad i n so r e t the wa el ngth f gl pe trum l ne Fo example th l r d k n be b erved in l ght f tl hyd ge l Hα

phones served by the same key equipment to the connection he may do so by operating keys pro vided for the purpose If he so desires he can then drop off the connection leaving the other party or parties connected

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Surface energy At an interf e tl ere will be a difference in the tendenci for eacl pha e t at tract it own molecule Con equently there i al way a minimum in tl e free energy of tl e surface at an interface the net amount of whi h i called tl e interfacial en gy At tl e water air interface f r xample tl liff r n e in m le ular f eld in the water an l air urfac a unt f r the inter facial en rgy of 72 erg /cm² a ial surface

If an ther pr sm s brought up to the first, as in F g 4 a part f the light i tr n mitted thro gh th e mb t on The f action t an m tted depends n th eparat o b twe n the pr sms The r fl ctiv ity a be m de as high a de ed In a filter the p m hypotenu e is oated with a l w ndex lay r f thi kne cho n to g e the p op r val ie of the refle t ity Thi i co ered w th a high ind x

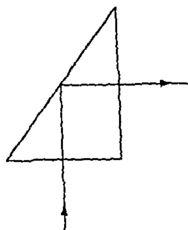


Fig 3 T l i t m l efl ct i ght-o gl p m

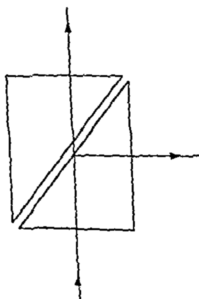


Fig 4 Frust at d t tal i t m l flect

l yer whos thi kne det rmi th w vel ngth f th p h d n the norm l F bry Pe t filter Th f ll wed by ec nd l w d x l ye and a sec nd pr m Th fi t fru tr ted reflecti at th bo d ry betwee the fir t pr m a d the low d l y r Th second flecti n i at th bo nd a y f th high i d x layer nd the second l w n d l y Th thi kn f th low ndex layer an be dj ted t g a y l of r flecti ty The filter i los l les th r i abso pt n with n the laye s The resulting filter can be made to ha e ba dwidth of l ss tha 6 A [B H BI]

Bibliography D E Gr y (ed) *American Insti tute of Phys cs Handbook* 1957

Interference of waves

Th p oce s whereby two or more waves of th same frequency o wavelength ombine to form a wa e wh s amplitud is the sum of th amplitudes of the interferin wa es The interfer ng waves can be electr magnetic acoustic or water wa es or in fact any p r odic disturbance

The m t tr k ng feature f int rference is the effect f add ng two wa e in wh ch the tr ugh f one wave co nc de with the peak of another If the two wa s ar f equal amplitude they can cancel e ch the out so that the re ulting ampl tude i zero Th s i perh p most dramat c in ound wa e t is p s ble to g ner te acousti wa es t arri e at a per n s ear o as to can el o t noise that is distu bing h m In opti s this cancellation can occur fo part cular wa elengths in a situation where white light is a urce The result ng light will appe r col r d This gi es rise to the ir d s-cent col rs f beetles w ngs and mothe -of pea l whe the s bstance in olved are a tually color less or t an pare t

Two beam interference Th qua titati e fe t res of the phenomenon can b dem n trated mo t eas ly by c ns d r ng two inte f ri wa es The amplitude of the fi st wa e at a part cul r point in p e an be written

$$A = A \; s\,n\,(\omega t + \varphi\;) \qquad (1)$$

wh re A_0 i the p ak ampl tude nd ω is 2π times the f equ ncy F r the second wa e

$$B = B \; s\,n\,(\omega t + \varphi_2) \qquad (2)$$

wher $\varphi_1 - \varphi$ i the ph e differen e betwe n th tw wav s In interfe ence th two wa s re u p mpo ed and th esulting w ve can be written

$$A + B = A \;\; \sin\,(\omega t + \varphi_1) + B_0 \;\; in\,(\omega t + \varphi_2) \qquad (3)$$

Th s can b e p nded to gi e

$$A + B = (A \;\; n\,\varphi_1 + B \;\; \sin\varphi_2)\cos\omega t + (A \;\; \cos\varphi \; + B_0 \; c\; s\,\varphi_2)\; s\,n\,\omega t \qquad (4)$$

By etting

$$A \;\; s\,n\,\varphi_1 + B_0 \sin\varphi_2 = C \sin\varphi_3 \qquad (5)$$

and

$$A_0 \;\; o\;\; \varphi \; + B \;\; \cos\varphi_2 = C\cos\varphi_3 \qquad (6)$$

Equati n (4) be omes

$$A + B = C\; s\,n\,(\omega t + \varphi\;) \qquad (7)$$

where

$$C^2 = A \;\; + B \;\; + 2A\;B \;\; co\;\;(\varphi_2 - \varphi_1) \qquad (8)$$

(s SUPERPO ITIO PRINCIPLE OF) Wh n C is less tha A or B the i t fe ence is called d tructi e

and thus the distribution of excited hydrogen over the disk can be determined

Most narrow band interference filters are based on the Fabry Perot interferometer (*see* INTERFEROMETRY) The Fabry Perot interference filter differs from the interferometer only in the thickness of the space between the partially reflecting layers In the interferometer this space can be several centimeters In the filter it is normally a few thousand angstroms In the simplest filter a glass plate is coated with a layer of silver which is covered by a layer of dielectric and in turn followed by another evaporated layer of semitransparent silver

Basic properties At all wavelengths at which the dielectric layer has an optical thickness of an integral number of half waves the filter will have a passband The number of half waves corresponding to a given passband is called the order of the passband The transmission T of the filter can be represented by the equation

$$T = \frac{t^2}{(1 - r)^2 + 4r \sin^2 (\delta/2)}$$

where r is the reflectivity of the silver film t the transmission of the film and

$$\delta = \frac{4\pi d}{\lambda} (n^2 - \sin^2 \theta)^{1/2} + 2y$$

where d is the thickness of the dielectric layer n its refractive index λ the wavelength y the phase shift experienced by the light at the metal dielectric boundary and θ is the angle of incidence

By inspection of this equation it is apparent that maxima occur when $\delta/2 = m\pi$ where m is an integer

Some of the quantities which are of interest to the user of these filters are (1) the peak transmission (2) the transmission between peaks (3) the bandwidth and (4) the angular field of view that is the angle through which the filter must be tilted to shift the wavelength of peak transmission a distance equal to the bandwidth

Each of these quantities can be determined theoretically from the preceding equation A typical filter has a peak transmission of 40% at its peak wavelength of 5461 A a transmission between peaks of 0 2% a bandwidth of 100 A and an angular field of view of 20 These numbers represent nearly the best that can be done with the simple metal dielectric filter

Multilayer types An increase in reflectivity can result in narrower bandwidths There are techniques by which high reflectivities can be achieved which are lossless that is which have no absorption This results in higher peak transmission and lower off peak transmission The first is the multilayer filter In this device the metal layers are replaced by a series of dielectric layers The boundary between two dielectric layers of refractive indices n_1 and n_2 has a reflecting power of perhaps 4% in the case of glass and air or less for two dielectrics whose indices are close together The value of the reflectivity r is given by the standard Fresnel reflection law

$$r = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

See REFLECTION (ELECTROMAGNETIC RADIATION)

By making several layers of alternate high and low index dielectric it is possible to reinforce the reflectivity of a single boundary and build it up by multiple reflection to any desired value It is necessary *only that the layers be of* such thickness that the reflections from successive boundaries are in phase When each layer is optically ¼ wavelength in thickness this reinforcement takes place A complete filter is sketched in Fig 1 It might consist of seven alternate layers of high and low index dielectric of a thickness of ¼ wavelength apiece followed by the dielectric spacer which is an integral number of half waves and which is followed by seven more ¼ wavelength layers The characteristics of such a filter are shown in Fig 2 For a seven layer reflection filter the reflectivity can be built up to 95% One would expect improvement over the metal filter and in fact the peak transmission of such a filter is as high as 80% and the bandwidth as low as 5 A

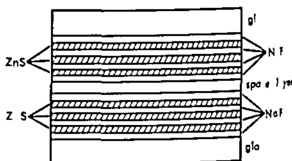


Fig 1 Schematic diagram of 7 layer solid Fabry Perot filter (From D E Gray ed American Institute of Physics Handbook McGraw Hill 1957)

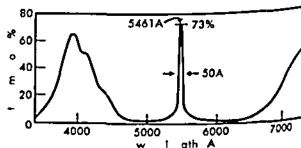


Fig 2 Transmission of filter shown in Fig 1 as a function of wavelength (From D E Gray ed American Institute of Physics Handbook McGraw Hill 1957)

Frustrated reflection A second technique is the use of frustrated total internal reflection for the partially reflecting layers of the filter Light is totally internally reflected when incident on the hypotenuse of a right angle prism as in Fig 3

wa es in Eqs. (1) and (2) s A and B respec ti ely When th pha e sh ft between them i ero the i t n ty f the resulting wave s

$$(A+B)^2 = A + 2AB + B \qquad (16)$$

Thi would seem to be a ol t on of the fi st law f thermody am c s this i greater th n the s m of th i d d al i t n it es In any p c fic ex per m nt howe er it t rns out that the e gy from the so r e t me ely ed tributed in sp ce The ex ces energy which pp a s whe e the int rf ren e i co tru ti e will d s ppear i tho e places wh re the en gy is destr ct e This is illust ated by th fr ng pattern in th Yo ng two-sl t e peri m t The energy on the s reen from e ch lit l n i giv by the expr ss on

$$E_1 = \int^{\infty} A^2 dy \qquad (17)$$

where A i th nten ty f the l ght from each sl t a gi n by Eq (10) The int ns ty from the tw sl t witho t nt feren e would be twic th s val e The inte ty w th i te ference s g v n by th p ess

$$F_2 = \int_0^{\infty} 4A^2 \cos\left[2\pi\left(\frac{yd}{l\lambda}\right)\right] dv \qquad (18)$$

The mp r o between 2E d E_2 n ed be m d ly a ge rrespond g t o e f ll cycl f f ges Thi m a that th a gum nt f th co- i Eq (18) need be taken ly fr m z r t Th c rr p d t a ti n of sc g ng f m the nt t a d ta e $y = l\lambda/2d$ F om th tw l t nd d ally the e gy n th s ection f sc een n be w tten

$$E_1 = 2\int^{l\lambda/2d} A \; d \; = \frac{A^2 l\lambda}{d} \qquad (19)$$

W th terfe c the energy is

$$E = \int^{l\lambda} 4A^2 \cos^2\left[2\pi\left(\frac{yd}{l\lambda}\right)\right] dy \qquad (20)$$

Th a be wr tte

$$F = \frac{l\lambda}{d}\int 4A \cos \varphi \, d\varphi = \frac{A_0 \, l\lambda}{d} \qquad (21)$$

Th s th t tal n gy f ll ng th reen i n t ha ged by the p esenc f i t rf c Th n ergy d ty at a p rt ular po t is, h wev r dr tic ll h ged Th f t s mo t import nt f those w es f th lect m gn tic p t um wh h be g n r ted by um t he scill t rs Th so ces f r d t nt a a be m de t em t t r nt w es wh h will u d rg t f en Th m k pos bl a ted t b t f the a f t t g Q i rr w beam f r dat n le p od ed I th proper ph g f l r t a y S A rr (r L)

The d uble sl t expe iment al pro ide a g od illu trat on of Niels Bohr s p inc ple of c mple mentarity F r deta led nformati n n th s s e QUANTUM MECHANICS

Fre el double mi ro A other way of plitting the li ht from the s urce is th Fre n l double mir ror This i llu trated in Fig 2. Light fr m the sl t S_0 f ll n two mirr rs M_1 and M wh ch are incl ed to each oth r at a ngle of the order f a deg ee On a c e n where the illumi at on fr m the two m rro s rl p there will appea a et of interf rence fringes The e are the same a the fri ges produc d n the tw lit e p r m nt s n e *the light on the c en ome f om the images of* th sl ts S_1 d S_2 f rmed by tl e tw m rr rs and these two images are the equ v lent of tw lits

Fr s l biprism A thi d way of plitting the sou ce s the F esnel b prism A k tch of a cross sect n of this d i e is sh wn i F 3 The light from the slit at S s tran m tted through th two h l es of the pr sm t the s re n Th b am fr m ach h lf will st ike th scre n at a d ffe ent angle and w ll appe r t c me from so rce which i slightly d splaced f m the o ig al lit The e two rt al slit a shown n the ketch at S_1 and S The p ation will depend o the di tance of the p ism f om the sl t S and o the a gle θ nd index of r fr ct on of th p m mat l In Fig 3 a i the d stance f the sl t f m the b prism a d l the d tance f the bip m f om th s e Th di tan e f the two v rtual sl ts f m the een is th s $a+l$ The eparat n of th tw v rtu l slit

$$d = 2a(\mu - 1)\theta \qquad (22)$$

wh μ is the refract ve index of the prism mate

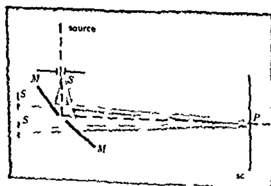


Fig 2 F l d uble-m i t rf c

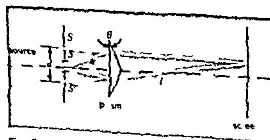


Fig 3 F nel b p m i t rfe e

When it is greater it is called constructive For electromagnetic radiation such as light the amplitude in Eq (7) represents an electric field strength This field is a vector quantity and is associated with a particular direction in space the direction being generally at right angles to the direction in which the wave is moving These electric vectors can be added even when they are not parallel For a discussion of the resulting interference phenomena *see* POLARIZED LIGHT

In the case of radio waves or microwaves which are generated with vacuum tube or solid state oscillators the frequency requirement for interference is easily met In the case of light waves it is more difficult Here the sources are generally radiating atoms The smallest frequency spread from such a light source will still have a bandwidth of the order of 10 cycles Such a bandwidth occurs in a single spectrum line and can be considered a result of the existence of wave trains no longer than 10^{8} sec The frequency spread associated with such a pulse can be written

$$\Delta f \backsimeq \frac{1}{2\pi t} \qquad (9)$$

where t is the pul e length This means that the amplitude and phase of the wave which is the sum of the waves from two such sources will shift at random in times shorter than 10^{8} sec In addition the direction of the electric vector will shift in these same time intervals Light which has such a random direction for the electric vector is termed unpolarized When the phase shifts and direction changes of the light vectors from two sources are identical the sources are termed coherent

Splitting of light sources To observe interference with waves generated by atomic or molecular transitions it is necessary to use a single source and to split the light from the source into parts which can then be recombined In this case the amplitude and phase changes occur simultaneously in each of the parts at the same time

Young s two slit experiment The simple t technique for producing a splitting from a single ource was done by T Young in 1801 and was one of the first demonstrations of the wave nature of light In this experiment a narrow slit is illuminated by a source and the light from this lit is cau ed to illuminate two adjacent slits The light

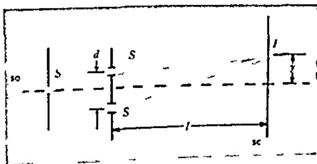


Fig 1 Yo g two-sl t I te fere ce

from these two parallel slits can interfere and the interference can be seen by letting the light from the two slits fall on a white creen The screen will be covered with a series of parallel fringe The location of these fringes can be derived approximately as follows In Fig 1 S_1 and S are the two slit separated by a di tance d Their plane is a di tance l from the screen Since the slit S_0 is equidistant from S_1 and S the intensity and pha e of the light at each slit will be the same The light falling on p from slit S_1 can be repre ented by

$$A = A_0 \sin 2\pi f\left(t - \frac{x_1}{c}\right) \qquad (10)$$

and from S_2

$$B = A_0 \sin 2\pi f\left(t - \frac{x_2}{c}\right) \qquad (11)$$

where f is the frequency t the time c the velocity of light x_1 and x_2 are the distances of P from S and S and A_0 is the amplitude This amplitude is assumed to be the same for each wave ince the slits are close together and x_1 and x_2 are thus nearly the same These equations are the ame as Eqs (1) and (2) with $\varphi_1 = x_1/c$ and $\varphi = x_2/c$ Accordingly the quare of the amplitude or the intensity at P can be written

$$I = 4A_0^2 \cos^2 \frac{2\pi f}{c}(x_1 - x_2) \qquad (12)$$

In general l is very much larger than y o that Eq (12) can be simplified to

$$I = 4A_0^2 \cos^2 \pi\left(\frac{yd}{l\lambda}\right) \qquad (13)$$

This is a maximum whenever

$$y = n\lambda\frac{l}{d} \qquad (14)$$

where n is an integer It is a minimum for

$$y = (n + \tfrac{1}{2})\lambda\frac{l}{d} \qquad (15)$$

Accordingly the screen i co ered with a er es of light and dark band whi h are called interference fringes If the source behind slit S i white light and thus I a wa elength varying perhap from 4000 A to 7000 A tl e fringe are i ible only where $x - x$ is a few wavelength that i here n is small At large alue of n the p ition of th nth fringe for red light will l e ery different from the p ition f r l lue ligl t and th fringe will l lend t gether and be wa hed out With monochromatic light the fringe will l e i il le ut t al ies of n whi h are determine l l y the diffra ti n pat tern of tl e lit For an xplanati n of thi *see* DIFFRACTION

Tl e ergy arried l y a wa e is mea ured l y the i ten ity which i equal to tl]uare cf the amplitud In tl prece ling exampl f tl e s perpo iti n of two wa tl e int tl e indi idual

Fig 7 Ll yd m i t rfe

Fig 8 I t f c by fl ct n f m d l ct ic pl

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flected at S Th xpe im ntal p of f thi 180
ph se h ft wa f w in tl e des pt n f nte
f w th l l yd m If th plate of m teri l
h f w r d x th th medi im wh h it
mm sed th d n mi t t ll be dded in
Eq (31) n w il be m efl ct d at S w ll
pe thi xt pha h ft Th pur ly p g
m t neces ty f h n ddit n l pha e h ft
be see l d g th i t n ty f th re
flected l ght h tl f S d S lm t
co l W th ut th t ph se hift th tw
flected beam ll be n ph nd the r flec
ld be t g Tl i rt l t pr r
t n f lm l an l g th k Con t u ti s
t f ll t k pl t w s l ngtl f wh h
d s a p ll l th f nges will be locat d
pt ll t f t If th n t pa llel d w ll
be f t f po t al ng tl u f es d
h f g w ll be l e ted n th u f Th
t t l th fr g w ll l pe d n th l e l
th p t l flect ty f tl f es
f g f pt l f Observat n of
t ng t tl type n be ed t d i m th
n l f Tl f t be tested f
t l se t plic ll fl t pl t M nocl r mat

l ght i reflected fr m th two urface and exam
ed a in Fig 8 On of th fir t exp r ments with
f inges f thi type was performed by S r I aac
Newton A conv x l ns i p e ed again t a gla s
plat and llumi ated with monochr matic light A
e s of ci c l r interfere ce fringes known as
Newt n s r gs appear a o d th p i t of contact
Fr m th eparatio b twee the f inges it i p
ble t determin the rad us of curvature of the
l n

Th n films I terference f i ges f this two-sur
f ce type are re p ible f r the col rs which ap
p ar n o l film fl ating o w t r He e the two
surface ar th il a r interf ce and the o l water
i te face The films are clo e t a is ble light
wavelength in thi kn If the thicknes is such
that in a particula d r ction destru t ve interfer
nce o cur f r gr en l ght r d a d blue will still
be eflected and the f lm w ll h a stro g p irple
appea an e Thi me ge e al phen menon is re
p ns ble f r th c l rs of beetl s w ng

Ch n eled sp ct m Amplit de plitting sh ws
cl a ly an th r o dition that must be sati fied for
t rf re ce to take pla e The beams fro n the
sou ce mu t not nly c me f m identical points
but they m st al o rigi ate f om the e p int t
e rly the me t me The light wh h s efle t d
from C in F g 8 orig ates fr m the o rce later
than the light wh h makes a do bl *traversal* be
twee S a d S If the s rfaces a e t f r apart
the spect al g s of co t u ti e and d tr cti
int rf n become so l se t gether that th y
ca ot be e lved In th ca of int rfe *enc* by
w vefr t pl tt ng the l ght fr m d ffe nt part
of so ce could only be con dered cohe ent if
xamined o e uff ntly h t tim i terv l In
the ase f amplitude spl tt ng the *nterf rence*
wl e s rf c s ar w dely separat d ca only be
ee if m n d r a uffc ntly na r w fre
qu cy int rval If th tw s rface are lluminated
w th wh t light and th eye is u ed as *the ana*
ly int fer e ca n t l e een when th epa
rat n is m re than a f w wa l ngth The nterval
between uc es s w l ngth *f con t u ti e in*
t rf r n be me o small th t each spectral re
gi n t wh ch *the eye* en ti e illumin t d
a d c l r een In thi ca e th terference
ag in be see by ex m ng th e fl ct d l ght
w th pect scope Th pe t m will be cro ed
with t l dark f i g at tho e wavelength s for
which th e i d t u ti nt f ence Th is i
c lled a ch nnel d pect m For large parat n
of the fa s the parat on betwee the w e
l ngth f destr t *interference* bec me small r
than th resoluti n of the spectr meter a d the
fr g r n lo g r vi bl

F s l co ff ci s Th ampl t de of the light
flect d at n rmal i ci l fr m a *d electr* su
fa i g n by th Fr nel ff ie t

$$A = A_0 \frac{n -}{n_1 +} \qquad (32)$$

rial This can be put in Eq (14) for the two slit interference pattern to give

$$y = n\lambda \frac{a + l}{2a(\mu - 1)\theta} \tag{23}$$

for the position of a bright fringe

A photograph of the experimental equipment for demonstrating interference with the Fresnel bi prism is shown in Fig 4 A typical fringe pattern is shown in Fig 5 This pattern was obtained with a mercury arc source which has several strong spectrum lines accounting in part for the intensity variation in the pattern The pattern is also modified by diffraction at the apex of the prism

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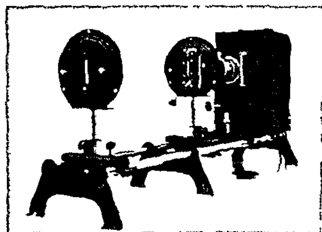


Fig 4 Equipment for demonstrating Fresnel biprism interference

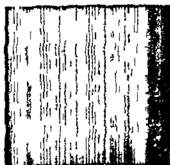


Fig 5 *Interference fringes formed with Fresnel bi prism and mercury arc light source*

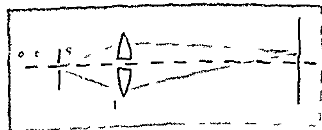


Fig 6 Billet split lens interference

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Amplitude splitting The interference experiments discussed have all been done by splitting the wavefront of the light coming from the source The *energy from the source can also be split in amplitude* With such amplitude splitting techniques, the light from the source falls on a surface which is partially reflecting Part of the light is *transmitted* part is reflected and after further manipulation these parts are recombined to give the interference In one type of experiment the light transmitted *through* the surface is reflected from a second surface back through the partially reflecting surface where it combines with the wave reflected from the first surface This is illustrated in Fig 8 Here the arrows represent the normal to the wavefront of the light passing through surface S_1 to surface S_2 The wave is incident at A and C The section at A is partially transmitted to B where it is again partially reflected to C The wave leaving C now consists of two parts one of which has traveled a longer distance than the other *These two waves will interfere* Let AD be the perpendicular from the ray at A to the ray going to C The path difference will be

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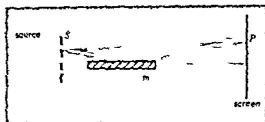


Fig 7 Lloyd m rr t rf e

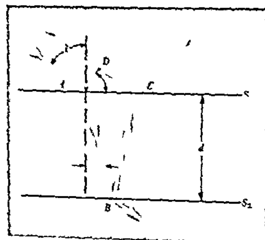


Fig 8 I terf by reflect f m a d l ct ic pl t

The phase d ff rence f π ad a s t added be a se f th ph h ft p ed by th l ght flected t S Th pe im tal proof f thi 180 ph se hift w s h w i th descript n f nt f ence w th Ll d m If the pl te f m t r l h a l w index th n th med m n wh h it mm rsed, th π ad n m t till be dded n Eq (31) w th b am fl ted at S will pen ce th t phase h ft Th pu ly p a m ti eces t f h n dd t onal pha h ft be seen b c n d th te ty f the r flected l ght wh th f ces S and S almo t co de W th t th t ph e hift th tw reflected be m w ld be ph a d th flee f film f a h thi k es Co tr t e n t f e ll t ke pla at wa elength f r wh ch $\Delta\varphi = \omega\pi$ h e m n t r If th f S a d S a pa all l, th f i ges w ll be loc ted be f ti f posit n l g th rf c s and th f es w ll be l cated a th u face Th ten ty of th f ges will d pend n th l e f th p rt l eflect ty f th u f es

T I pt al fa Observ t f fri es f th t pe n b used t d t m n th f t f a f e The f e t be tested t pt ll fl t pl te M nochr m t l ht i reflected from the two urfa es and e am ned a in Fi 8 One of th fi t experiment w th fri es f thi type wa perf rmed by S r I aac Newt n A c n x len i pres ed again t a gla pl te a d llumin ted w th m nochromatic light A er es of ci cular i te f rence fr nges known as N wt n s ri s appea a ound the po nt f c ntact From th e p a at on b tween the fr nge it i pos sible t determine the rad us of curvature f the l ns

Th film Int rference fringes of thi two ur f ce typ a e resp n ible for th e ol rs which ap p ar in il film fl ati g n water H r the two u fac are th oil a r int rfac and the o l water interface The film are cl se t a i ible light w len th n th kn If the th ckness i uch th t n a pa ticular d ection destructi e interfer nce occurs f r green l ght red and blue w ll till be r flect d and th film will ha e a tr ng purple ppearan e Th ame g eral ph n menon i re po ibl for the color of beetle wi g

Chann led p trum Ampl tude pl tti g hows cle rly an the c ndit on that mu t b at fied for inte f re c to take pl ce Th beam fr m the ur e mu t n t only c me fr m id nt c l p nt but they mu t al o riginat fr m th points at ly the ame time The light wh ch s reflected f om C Fi 8 ori nate f m the so rce lat r tha the l ght wh h m kes a d uble tra e s l be tween S nd S If th e urfa are t o f apart th pectr l r g ns of c truct and de tructive interfer nce be me so clo t gether that they c n t be resol ed I the a e of i terfere ce by wa ef ont pl tti g the l ht fr m d fferent part of a ou e c uld only be con idered coh nt if exami ed o a ffi ie tly h rt t me i t rval In the c se of n pl tude pl it g th interf ren e wh n urfa es e w dely parated an only be se n f exam ed o r a suffi ie tly a row f quen nt r l. If th tw su faces a e lluminated with white l ght nd the e u d as th a a l z r inte f en c n t be en when the epa rat on m r tha a f w w ele th The interval b twee c es wa lengths f co truct n t fere e becomes o mall that e ch sp ctral r g t wh l th e) s n ti i llum ated and n l ee In th s a th interfe e ce n g in be een by exa n ni the efl ted l ght w th pect cope The pect um will be cros ed w th set f da k f ges t th w v l gths f r wh h th s d t ucti e nte feren e Thi call d a han l d pectrum F larg ep at o f th urf ces th ep r t on between th wa e l gth of de-tru t e i te f rence becomes m ll r h th resolut f th spect om t nd th f ges a n f n ibl

F l co ffici t Th ampl t d of th l ght e flected t n rm l id n f om d electri ur f g n b the F es el c effi ent

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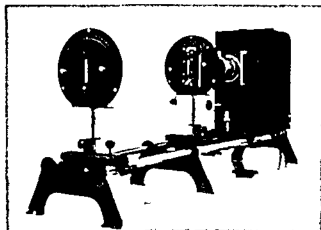


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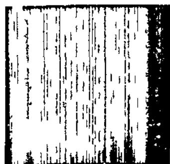


Fig 5 Interference fringes formed with Fresnel biprism and mercury-arc light source

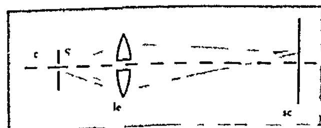


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source S P m sc en

Fig 7 Ll yd' m int rf e

D A t S d B S

Fig 8 I terf by flectio f m d lect ic plat

The ph d ff f − d n added be- se f th ph se h ft p ced by the l ght effect d t S The exp rim t l p oof f th 180 phase h ft wa h wn th des ript of nte f e w th Llo d mirr If the pl te f materi l h a l w nd x th n th med m wh h t imm sed th r d n mu t t'll be dded Eq (31) n w th be m fi ted t S will peri th e t a ph se hift Th p ely p g m t neces t f h n dd ti al pha e h ft a be een by der ng th ten ty f th e- flected l ght when th f S a d S lm t d W th t th t a ph se hift, th tw flected be m w ld be n ph d the r flec t w uld be t ng Th rta nly t p per f film f a hi g th k es Con t t rf en w ll t k pl t wa l gth f wh h $\Delta\varphi = 2m$ wh m t g If th u f es S d S p ll l th fri ges w'll be loc t d pt ll t i fin t If th a t p r ll l d w ll be f t f pos t l g th fa and th f g w ll be loc t d th u f e The n- t n t f th f ges w ll d pe d n th l f th p rtial flectiv ty f th u faces

T t g f pt al f e Observ t o f ges l th t pe n be u d t d t rm n th t f fa Th u f e t be tested p t lose t pt lly fl t pl t M noch mat

li ht t r flected f m the two urfaces and exam ined a in F g 8 O of the first periment with frin es f thi type was performed by S r I ac Newto A n x l ns i pres ed agai t a gla plate and illuminated with m nochr mati light A ser es of circular int rfe e e fringes known as Newt n ings appe r a u d the po t f c ntact. From th p r t on between the fringes it i pos- s bl to d t rm ne the rad us of curvature of the l ns.

Thi films I t rf rence frin es f thi two- ur f ce type a e respo ble for the col rs which ap- p a in l film fl at g n wate Here th two urfaces re the o l a int fa e a d the o l water i terf ce The films a cl se to a i ble light wa elength in th ckne If the thi kne i ch that, in a part cula d rect n destructi e interfer n e occ rs f r green light, red and blue will till be reflected a d the film will ha e a tr ng purpl ppeara ce Thi am gene al phenomenon i re- po ble f r the col f beetles wing

Chann l d pect m Ampl tude pl tting how clearly n ther co d t on that mu t be ti fied for terf n t tak pl e The beam f m the sourc m t n t nl c me f m ident l points, but they mu t l o orig n t f om these po nt at nea ly the same tim Th l ght wl ch i r flected f m *C* Fig 8 rigin tes fr m the source l t r tl n the light which makes a doubl tr ersal be- tween *S* and *S* If the u face are too f r apart the spect l r gi n f co tru t a d destructi e nt rfe ence becom o close togeth r that they cann t be esolved I the ase f i terf rence b wa fro t plitt ng the light fr m diff re t part f a so r e could nly be n dered c he e t if ex m ned *o* r uffi tly sh rt tim int rval In th ca of ampl tude pl tt ng the *interfe* e ce wh n u f ces a e wid ly sep rated can onl be se if xamined er a uffi entl arrow fre q ncy i terv l If the tw urfa es ar ll *mi* ted w th white light and the ey is used as th ana lyze nte fere e a ot be een when th sepa r t n m th few wa l ngth Th nter al between cce-siv w ele gth f co truct n t f bec mes mall th t ach pect al e- gi n to wh h th eye i sen t s 'll minated and n col i seen In this c th nterf ce c n a ain be see by x min ng th eflected l ght with pect ope Th pectrum will be cro ed with a et of d k fringes t those w v l gths for which th destruct e te f ren e Th c lled a ch n ele l pectrum Fo large ep r t o f th urf ces the p t o between th wa e- l gth f destru t e t rf n e becomes m ller than the resolut n f th pect meter nd the f nges en lo vi bl

F es l co ffici t The mpl tude of the light flected at rmal incid n e f m a d lectr c ur f ce given by th F es el oeffi nt

$$A - A \frac{n - n}{n +} \quad (3)$$

where A_0 is the amplitude of the incident wave and n_1 and n_2 are the refractive indices of the materials in the order in which they are encountered by the light In the simple case of a dielectric sheet the intensity of the light reflected normally will be

$$C = A + B^2 + 2AB \cos \varphi \qquad (33)$$

where B is the amplitude of the wave which has passed through the sheet and is reflected from the second surface and back through the sheet to join A The value of B is given by

$$B = \frac{n_2 - n_3}{n_2 + n_3} \qquad (34)$$

where the approximation is made that the intensity of the light is unchanged by passing through the first surface and where n_3 is the index of the material at the boundary of the far side of the sheet

Nonreflecting film An interesting application of Eq (33) is the nonreflecting film A single dielectric layer is evaporated onto a glass surface to reduce the reflectivity of the surface to the smallest possible value From Eq (33) it is clear that this takes place when $\cos \varphi = -1$ If the surface is used in an instrument with a broad spectral range such as a visual device the film thickness should be adjusted to put the interference minimum in the first order and in the middle of the desired spectral range For the eye this wavelength is approximately in the yellow so that such films reflect in the red and blue and appear purple The index of the film should be cho en to make $C^2 = 0$ At this point

$$(A - B)^2 = 0 \qquad (35)$$

$$\frac{n_1 - n_2}{n_1 + n_2} = \frac{n_2 - n_3}{n_2 + n_3} \qquad (36)$$

$$n_1 n \; - n \; + n_1 n_3 - n \, n_3 = n_1 n \; - n_1 n_3 + n_2 \; - n_2 n_3 \qquad (37)$$

Thi can l e reduced to

$$n = \sqrt{n_1 n_3} \qquad (38)$$

In the case of a gla s surface in air $n_1 = 1$ and $n_3 \simeq 1\,5$ *Magne ium fluoride i a sul stance* which is frequently u ed as a nonreflecti e coating ince it is hard and approximately sati fies the relati n ship of Eq (38) The purp e of reducing the re flection from an optical element i to increa e it tran mi sion ince the energy which is not reflected i tran mitted In the ca e of a ingle element th i increa e i not particularly important S me optical in truments may ha e 15 20 air gla surface h w e er and the coating of th e e surface give a tre mend us increa e in tran mi ion

Haidinger fringes When the second surface in two- urface interference is partially reflecting in terference can al o l e ol erved in the wave trans- mitted thr ugh b th surface The interf rence fringe will l e complementary t tho e app earing in reflection Their location will depend on the parallelism of the surfaces For plane parallel faces *the fringes will appear at infinity and* will be concentric rings The e were fir t ob erved l W K Haidinger and are called Haidinger fringes

Multiple beam interference If the urfaces S_1 and S are strongly reflecting it i nece ary to consider multiple reflections between them For air glass surfaces this does not apply since the reflec tivity is of the order of 4% and the twice-reflected beam is much reduced in intensity

In Fig 9 the situation in which the urfaces S and S have reflectivities r_1 and r_2 is hown The space between the surfaces has an index n and thickne s d An incident light beam of amplitude A is partially reflected at the fir t surface The tran mitted component is reflected at S and is reflected *back to S_1 where a econd splitting* takes place Th is repeated Each succes ive component of the wa es leaving S_1 is retarded with respect to the next The amount of each retardation is gi en l y

$$\varphi = \frac{4\pi n d}{\lambda} \cos \theta \qquad (39)$$

Equation (7) was derived for the superp ition of two waves It is possible to derive a similar ex pre sion for the superposition of many wave From Fig 9 the different waves at a plane ome here above S_1 can be represented *l y the following* ex pres ions

Incomin wave $= A \sin \omega t$ (40)
First reflecte l wave $= Ar_1 \sin \omega t$
Secon l reflected wave $= A(1 - r_1^2) r_2 \sin (\omega t + \varphi)$
Third reflected wave $= -A(1 - r_1^2) r_1 r_2^2 \sin (\omega t + \varphi$

By inspection of the e terms one can write do n the complete series As in Eq (3) the ine term can be broken down and coefficients collected simpler method is to multiply each term by i $\sqrt{-1}$ and add a co ine term with the ame coeff cient and argument The individual term then ar all of the form

$$Be^{-i\omega} e^{-\;m} \qquad (41)$$

where m is an integer

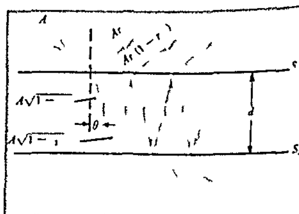


Fig 9 M lt pl flect o of a wa e b twe tw s f c

10 Th h pe of m lt ple-b m f g f df t l f f fl ct ty

n b a ly mmed F r th r flected wa bt n

$$R = \frac{\quad + \quad e^{-}}{1 + \quad e^{-}} \qquad (42)$$

n a n tl two-be m a e th n mum n the t ity R i obt d wh $\varphi = N\pi$ wl e N s odd int g d = Tl f ng hap h w n b q it d ff r t from th l e a nd ng th alues of th fl t t s and Th g at th e al th sharp beco f ge

t wa h w rl e how two-b m nterf en ld be u d t me r the to f a urfa e th t bn qu a fl t gla test pl t wa pl ced r th rf t be x m d d m n h mat c f n f ges e e form d b tween th te t f e d the f c f the pl te Th e t o- m f i g h e t n ti wh h v ry th e q a d of the p th d ffe n It y icult w th h f nge t d t t i t s n ge t ght o th t rm v i ti n of f pla a ty th t re m ll than 1/60 w e- gth If th rf t be e am ed s o ted with r nd the t r f e l at d w tl p ly t mitt g m t ll at the fle ti t i es t p t wh e m y be m e ol ed the f rmat f the nt rf r e f i e Th pe of th f ng s s g n by Eq (42) Th shape f g f d ff r nt v l s f h wn in F g W th h gh fl t ty f ng th se it t t part f m pla ty s n ea d f r beyo d w l gth

t i th po bl w th p t lly il d rf c g t a m h bett pt t f m ll g l t s with ted f es Th nc a se ty h th t t ps in l a d m s m ll A n h ght ca be s b e min g th mo o- mat i t f f ng p od ced b tween a ilvered mica u face and a partially il red gla flat Se INTERFERENCE FILTER OPTICAL IN TERFERO IETRY [B H BI]

B bl o aphy M B r and E Wolf *Princip! s of Optic* 1959 O S Hea ns *Opt cal P operties of Th Sol d F lms* 19 5 F A Jenkins and H E Wh te *Fund m ntals of Phys cal Optics* 3d ed 1957 J St o g *Conc pts of Clas ical Opt cs* 19 8

Interferometer acoustic

A device f mea uring th v l city nd att n iatio f ound wa e i a gas or l qu d It operates by s nding an ltra n c beam of s nd wa es thro gh the med um t be mea u ed in o der to obtain a ta di g w e sy tem between the dri ing cry tal nd a r fl t r who e di tance fr m the crystal can be a ed by a c ew sy te n Th illu tration show a typ cal system f r tudyi g the v lo ty and at tenuatio of a ga at vario tempe atu es The t p pa t of th llustratio show a sy tem for purify g the g s which is th n adm tted t th interf ro- m tric chambe sh wn at th bottom The wl le n t i placed in a therm tated b ting co l wl ich m k t p ibl t regul te the temperatur w th clo e l m ts

An o llat r s ttached t the rystal nd tuned t the ry t l re nant fr que y The ariat n in

A t ht rf m te f m g th l city and tt t f d w g

the amplitude of current from the oscillator is measured as the distance between the crystal and the reflector is varied. At half wavelength intervals sharp dips occur in the received current indicating that a high mechanical impedance is impressed on the end of the vibrating crystal by the standing wave system between the crystal surface and the reflecting plate. By counting the number of half wavelengths n occurring in a given displacement l of the reflecting plate and knowing accurately the frequency of vibration f, one determines the velocity of propagation v by the formula

$$v = \frac{2lf}{n}$$

The attenuation can be determined by the rate at which the maximum and minimum current values change with distance. Such instruments can measure velocities to within 1 part in 10 000 and attenuation values within a few per cent. *See* ULTRASONICS. [W P M]

Interferometry

The design and use of optical interferometer devices in which interference of light is used as a tool in metrology and spectroscopy. These uses include precise measurement of wavelength, the measurement of very small distances and thicknesses by using known wavelength, the detailed study of the hyperfine structure of spectrum lines, the precise determination of refractive indices, and in astronomy the measurement of binary star separations and the diameters of stars. Optical interferometers are based on both two-beam interference and multiple-beam interference. They are also based on wavefront splitting and amplitude splitting.

Rayleigh interferometer Perhaps the simplest type of interferometer is the Rayleigh interferometer, which is essentially a modification of the instrument used in Young's double slit interference experiment (*see* INTERFERENCE OF WAVES). In Young's experiment the two slits are on the order of 1 mm apart. In the Rayleigh instrument (Fig 1) the two slits S_1 and S_2 are of the order of 1 cm apart and $\frac{1}{4}$ cm wide. They are illuminated with parallel light from a lens L_1 at whose focus is a single narrow slit S. A second lens L_2 spaced several centimeters from the first brings the two beams to a focus where interference fringes become visible. The instrument is used to measure the refractive indices of liquids and gases, and in this fashion can serve also as a means of chemical analysis.

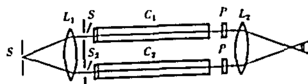


Fig 1 Rayleigh interferometer

Cells (C_1 and C_2 in Fig 1) are placed in front of each slit and matched so that when empty the central bright fringe in the interference pattern is undisplaced. The material of interest is then placed in one cell and the comparison material in the other. If the refractive indices of these two materials are different, the fringes will shift, and this shift is a measure of the index difference.

To make the fringe shift easy to detect, the cells are built to cover only half of the length of each slit. At the focus of the second lens there will accordingly appear two sets of fringes separated vertically from each other. One set involves a part of the beams which does not pass through the cell. It remains motionless when a gas or liquid is put into either cell and acts thus as a series of reference marks for the displacement. In front of the cells are two plates of glass P_1 and P_2. These add a retardation $(\mu - 1)t$ to each beam, where μ is the index of refraction of the glass and t is its thickness. One of the plates can be tilted, thus adding a phase shift to one of the beams. When the phase shift is equal and opposite to the phase difference in the beams caused by the refractive index difference between the contents of the two cells, the fringes will be displaced back to the zero position. They will then match the fringes produced by the beams which do not pass through the cell. In this way the instrument can be operated in a null fashion and becomes much more precise than if an attempt were made to measure the fringe shifts with a scale.

The Rayleigh interferometer is an extremely sensitive tool for the detection of impurities in gases and solution. With 100 cm cells, helium in air can be detected at a concentration of 60 parts in 10^6. This represents an index difference of approximately 1 × 10

Michelson stellar interferometer This device solves most dramatically the problem of measuring the diameters of stars, which are as small as 0.01 sec of arc. This task is impossible with an optical telescope, since the resolution obtainable even with the largest is not much better than 1 sec of arc.

The Michelson stellar interferometer is a simple adaptation of Young's two slit experiment. In its first form, two slits were placed over the aperture of a telescope. If the object being observed were a true point source, the image would be crossed with a set of interference bands. A second point source separated by a small angle from the first would produce a second set of fringes. At certain values of this angle the bright fringes in one set will coincide with the dark fringes in the second set. The smallest angle α at which the coincidence occurs will be that angle subtended at the slits by the separation of the peak of the central bright fringe from the nearest dark fringe. This angle is given by the expression

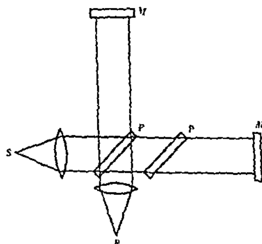
$$\frac{\lambda}{2d} = \alpha \qquad (1)$$

wh e d s th eparat n of the sl t λ th d mi nant wa ele gth of the two ur e and α their an gular p ratio Th measur me t f th separa ti of the our e i p rf rmed by adju t ng th p rati n d b tw e the slit until the fring n h

Con de w a singl ource in the hape of a l t f fi te width If th lit subt nd an ngle t th t l ope pert e wh h i la g r than α the t te fer f inge w ll b red ed in ntra t F r ari l lements at one de f tl lit there will be l ment an angl α way whi h will can l th f ing fr m th fi t eleme t By induc t n it l a that for a epa at d uch that th l t u e btends an a le

$$\alpha = \frac{\lambda}{d} \tag{2}$$

the f ges f om a n l l t w ll am h m pl tely F r add t n l f m t on n th M chel on t lla t f m t s DIFFR CTION



Fg 2 M h l i f m t (F m A C H dy o d F H P Th P pl f Opt M G w H ll 1932)

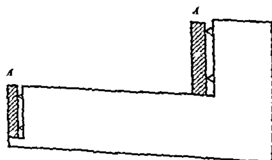
Michelson interferometer Th M hel n te f m t (F g 2) i ba ed on ampl t de pl tt ng Light f m na w ngl u S i id nt at 45 n a 50 p rtially fl t g plat P H lf th light t a mitt d to mi or M wh h refle ts t b k t th 50 flect g pl te Th l ght wh h r fl t d p se d t M wh ch fl ct it b ck t P At P the tw w s a g n part lly r fl t d nd p rt lly t n m tted nd a p rt of h wa p oceed t th r R whi h ma be a r ph t ll a h man ye Dep ding n th d ff e c b tw e th d t n e fr m th be m pl tt t th m r s M and M the t be m will t rf n t ti el o d struct vely Th plat P mp t f the th kn s f P

Wh th m rr rs mag a compl tely p al l l the i t rf nc f g s are i l Th flec ti ty f th m rs th M h l n t rf rome t r can be m d high a d ed a d the interferenc will till be two-beam interference The int n ty f the fri ges can accordingly be made ery g at If the m rror ar sl gh tly incl ned about a ert al a is vertical fr nge are fo med ro s the fi ld of vi w The e fringe can be f rmed in wh te light if the path differen e in part f the feld of view s made z ro Ju t as in other in terfer ce experiment only a f w fringe will appear in whit l ght beca e the d fference in path will be differ nt for wa el ngths of diffe ent colors Acc rd ngly the f ing s will appear col red cl e to zer path difference and will di appear at larger path d ff rences wher th je tral eparat on of the ce ive r gions f con tru tive interferenc is too clo e for the eye to ee color Th f inge of ero path diff ren e i black and n l e a ily d t g i hed from the n ighboring fri ges Thi mak s u e f the in trum nt relat vely ea y The n iti ity to weak l n a d re luti n of the interferomet r i thu p t nt ally ry much g eater th a that f an opti al *spectr meter*

Etal ns As a m as ing de i the m rror M i u ually mounted n a crew that the *path d ffer ence* an be alt red As the crew i turned tl e f inge appear t m e and may be c nted F r l ght of the requ red deg ee of m no hromati ity the path diffe ence betwe n M and M_2 can b m de ev ral ce timete l f e the fri ge b come too wa h d out t ount

The red l e of cadmium wa di covered by A A M h l on to be narrow r th n any ther u ce ava lable at the t m One of th early u e M chel on made of h s d v ce w s n the me rement f the tand rd met r in t rm f th s r d cadmium l e The m r or M was r pla d f r the p rpose by p i of mi ro s m u ted a in *Fig 3 This a* rangement s te med an talon The talo mirrors w f such z that two et lons c uld be pla ed de by s d in the field f view

Se ral f the etal s we bu lt Each w s tw e th length f th next small r The large t w s 10 cm and the s alle t 0 0391 cm F r t the malle t was t up al n and the mi ro M ad j st d w th h t l ght til the bl k fringe was c nt r d At this po t the m ror M and one mi ror f th et lon were equ di tant fro n th beam pl tt W th r d dm m light th e m ro M_1 w s



Fg 3 A t lon w th tw d u t bl m rs A a d A t w h th Mich lso i t rf omet ds t m m t

then moved and fringes counted until the distance of mirror M_1 from the beam splitter was equal to the distance from the beam splitter of the mirror at the other end of the etalon. This operation gave the length of the smallest etalon in terms of the red cadmium line. The second etalon was then placed beside the first and their end mirrors aligned with the interferometer until both showed the black white-light fringe. This signified that the two mirrors were exactly the same distance from the beam splitter. The movable mirror M_1 was then shifted until the white-light fringe appeared at the other end of the smallest etalon. This etalon was then moved until the white-light fringe appeared in the mirror at its other end. It had then been shifted a distance exactly equal to the separation between its two mirrors. Again mirror M_1 was moved until the black fringe appeared in the mirror at the other end of the etalon. This mirror was then separated from the scan mirror of the second largest etalon by a distance equal to twice the length of the smallest etalon. If the larger etalon were exactly equal to twice the smallest, a white-light fringe would appear in its mirror also. With monochromatic light it was easy to count the fringes which represented the differential between the two mirrors. A repetition of this procedure with larger etalons gave an exact measure of the length of the 10 cm etalon. The meter was then measured by repeating the mirror alignment procedure with 10 successive shifts of this longest etalon. By a recent repetition of these measurements the length of the meter was determined to be 1 553 164.1 wavelengths of the cadmium red line in standard air.

Interference spectroscope. The Michelson interferometer is also interesting as a spectroscope. Consider first the case of two close spectrum lines as a light source for the instrument. As the mirror M_1 is shifted, fringes from each line will cross the field. At certain path differences between M_1 and M_2 the fringes will be out of phase and will essentially disappear; at other points they will be in phase and will be reinforced. By measuring the distance between successive maxima in fringe contrast, it is possible to determine the wavelength difference between the lines.

This is a simple illustration of a very broad use for any two-beam interferometer. As the path length t is changed, the variation in intensity of the light coming from an interferometer gives information on the basis of which the spectrum of the input light can be derived. The equation for the intensity of the emergent energy can be written

$$I(t) = \int_0^\infty I(\lambda) \cos^2 \frac{\beta t}{\lambda} d\lambda \qquad (3)$$

where β is a constant and $I(\lambda)$ is the intensity of the incident light at different wavelengths λ. This equation applies when the mirror M_1 is moved linearly with time from the position where the path difference with M_2 is zero to a position which depends on the longest wavelength in the spectrum to be examined. From Eq. (3) it is possible mathematically to recover the spectrum $I(\lambda)$. In certain situations, such as in the infrared beyond 1.5 μ, this technique has several advantages over conventional spectroscopy. The detector looks at all wavelengths 50% of the time. The integration time is equal to one half the length of time taken by the whole scan. In a conventional infrared spectrometer the integration time is the time taken by the monochromator slit to traverse one resolvable unit of wavelength (*see* INFRARED SPECTROSCOPY). For a discussion of the use of the Michelson interferometer in the celebrated Michelson-Morley experiment, *see* LIGHT.

Fabry-Perot interferometer. A simpler device than the Michelson interferometer is the Fabry-Perot interferometer sketched in Fig. 4. The two glass plates are partially silvered on the inner surfaces, and the incoming wave is multiply reflected between the two surfaces. Hence the device is called a multiple-beam interferometer.

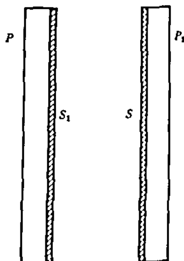


Fig. 4. Fabry-Perot interferometer. P_1 and P_2, glass plates; S_1 and S_2, partially transmitting layers of silver.

The Fabry-Perot interferometer is used in transmission. The expression for transmission T is

$$T = \frac{t^2}{(1 - r)^2 + 4r \sin^2 [(2\pi nd/\lambda) \cos \theta + \gamma]} \qquad (4)$$

where d is the separation of the surfaces, θ the angle of incidence, γ the phase shift for a reflection at the silver surface, t the transmission of the silver surface, r its reflectivity, and n the refractive index of the air between the plates. When a monochromatic light source is viewed through the interferometer, it will appear as a series of rings. These occur at those angles which make

$$\cos \theta = \frac{(m\pi - \gamma)\lambda_0}{2\pi nd} \qquad (5)$$

where λ_0 is the wavelength of the light and m is an integer.

If a series of spectrum lines is transmitted through the instrument, th an [illegible]

fringe with order number m m y overlap a fringe f o de $m+1$ a oci ted witl a c d line Two l n wh ch would o erlap ex ctly ar gi en by the eq t s

$$\lambda = \frac{\angle nd \quad \theta}{m} \qquad \lambda_2 = \frac{2nd\, c\; s\, \theta}{m+1} \tag{6}$$

The diff n e can be w itt n

$$\Delta\lambda = \frac{\lambda_1 \lambda}{2nd \;\; os\, \theta} \tag{7}$$

I term of w e number and at mall angles of i c dence th s eq t n ca be simpl fied t

$$\Delta \;\; = \frac{1}{2nd} \tag{8}$$

An i t rf r meter f sep r ti n d c n be used pectr graph wl e e f a freq ncy i terval Δ the is n o lapping Th s qua tity is alled the f ee sp ctral ra g The re lut n i given by th sep r t n f two w le gths wh e fringes o rlap t th 50% el tive tran m po nt Thi epar tion c b written

$$d\lambda = \frac{2\lambda \;\; in^{-} \;\; [(1 - \;)/(2\sqrt{\;})]}{m\pi - y} \tag{9}$$

A int esti g e p i n is the es lut on n t rm of free p t al ange Whe y i neglected thi g n by the f rm ila

$$\frac{d}{\Delta} = \frac{2}{\pi} si^{-1}\left(\frac{1-r}{\sqrt{\;}}\right) \tag{10}$$

R fl ct t ngs The er pr al of this num ber the esol i g p we i term of f ee p ctr l ng n b d d a mea u e f the perfo m an e f a set f Fab y P r t pl tes used pect o- gr ph c lly W th a outi e l r o t g the e- sol ng pow n term of f ee pectr l ang i of the d f 20 H gh r eflect ties an mp e th s number b t th t a mi on f th c t g d p t u h les l th t the xp e tim b om s too l ng High lvi p w l b g ns to p t rv t nge t r q me t n th flatne s nd moothn of th pl te Temp r t a d t es- t s d ng th xp ure tim w ll lso ffect the r lut n On way f imp g th in t f m t th gh the u e f m lt ple d lec g t A typ l l e l y ha t an mi n f 4% nd effect tv f 93% W th a d lectric ati g the flect ty e r ge f eve l h d ed g t m be s h gh as 99% a d the t m 98% S e REFLECTIO (E CTRO TAG- E IC R I T) RE LIING POW (OPTICS)

Sp t l g It d ffi lt t a h with a pect gr ph sol g p e that h gh th f w h nd ed f th a d Th p ctr l r nge h eve an be seve al th a d g t om A F bry P t nte f m ter i fr qu tly u ed in t n fr m th pect g aph p esent th mallest f ee spectr l range req i ed of the nt rf rometer In th fa h n re ol i g powe s of se eral m lli n can be a h eved and the hyperfine tru ture and isotope hifts of atom c pectra ha e been disco e ed and st d ed

Mach Zehnder interferometer The M ch Zehn de i t rf r met r ketched in Fig 5 is a a iat n f the M hel o nt rfe m ter a d l k the Mi helson in trum nt depend ampl tud pl tti g f the w efr nt L ght ente s the i trument and is fl ted a d tr m tted by th m tra parent m rr r M The refle ted port on proceeds to M wh e it i reflected tl ugh the cell C_2 to the emi t an pa ent m rror M Here it mb nes with the l ght tran m tted by M to p od c nt fer nce The l ght t a m tted by M p es th ough a c ll C which i mil to C_2 and s u d to compe ate fo th wind ws f C_1

Th m jor appl ation f th s in trument i n studying flow a ou d models f ai craft mis- s le o p jectiles The obje t and a oci ted a r t am r pla ed in o e arm of the int rferometer B au th a p s re s a it fl ws o r the mod l the i d x f r f ct n ar and thu the ffe t path length f the l ght n th s beam is a fu t on of p t on Wl e th sa t n is an odd umber f h lf wa es the l ght w ll nt fe e d stru t ly d da k fr ge will appea in th fi ld f w From a phot graph of the f ing s the fl w patt n c n be mathemat cally deri ed

Thi appl c t on h w the two main feat r wh h d ti gu h th i st um t f om th M chel s n nte f m ter The l ght goes thr ugh a h path in the i str m nt only nce whe ea i M chelson s d i th l ght tra er es ch path twice Th do ble t l make th Mi h lson te f omet xt emely diffc lt to us n appl t ons wh e pat al lo t n f nd ar at o s de i ed The i com ng and outgoing b ms t nd to tr el o e l gl tly d ff ent p th a d this lowe s the r ol t o bec e of th i d x grad ent ac the field I th M helson int rfer met r th

Fg 5 M h Z h d r int rf met

fringes are located at the virtual inter ection of the two reflecting mirrors In the Mach Zehnder device the mirrors can be adjusted so that the fringes are located at the plane of the model being tudied In this fashion they can be photographed simultane ously with the model so that their geometric po i tion with respect to the model can be precisely de termined *See* SHOCK WAVE DISPLAY [B H BI]

Biblio raphy *J phys radium* vol 19 no 3 1958 J Strong *Concepts of Classical Optics* 1958 S Tolansky *An Introduction to Interferometry* 1955 W E Williams *Applications of Interferometry* 1930

Intermediate frequency amplifier

A tuned amplifier employed in the amplification of the signals produced by the mixer in a radio re ceiver Becau e the carrier frequency of the modu lated signal from the mixer is es entially constant the resonant frequency of the amplifier is a fixed value

The proper design of the intermediate frequency (i f) amplifier is e ential for good electivity and reproduction of the original transmitted ignal If the amplifier is tuned too harply the high fre quency components of the modulating signal will be lost To avoid this stagger tuning of the individ ual tages may be u ed In a stagger tuned ampli fier the resonant frequency of each stage is slightly different from the carrier frequency with the re sult that the gain is e entially constant over the bandwidth of the modulated signal The gain de creases rapidly at frequencies outside this band

The standard i f frequency for broadca t radio receivers is 455 kc other frequencies are u ed de pending upon the particular application uch a televi i n recei er or radar recei er *See* AMPLI FIER [H F K]

Intermetallic compounds

If two metal are melted together in certain propor tions the re ult i generally an alloy It i al o p s ible to form alloys by solid tate rea ti n by ap plication of the p wder metallurgy technique Depending on the comp nent metal and their pr portion the alloy may con i t of a ingle pha e or of everal phase Single pha e alloys may be ei ther of the lid luti n type or intermetallic om p und According to the *Handbook of Metals* an intermetalli c mp und is defined a a compound

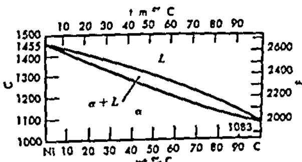


Fig 1 Coppe -n ck l phase d ag am

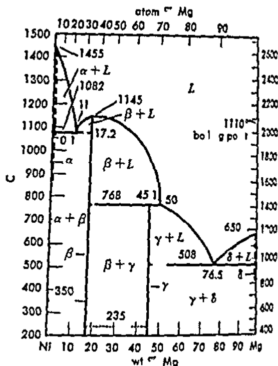


Fig 2 Magnes um n ckel phase d agram

of two or more metals with a characteri tic crystal structure and may have a definite compo iti n or range of compositions corresponding to a olid o lution

The difference between olid olution alloys a d intermetallic compound can be t l e sh wn b com pari on of characteri tic pha e diagram Figure 1 shows the pha e diagram of two components (f r example copper and nickel) which form a ld oluti n alloy a typical pha e diagram for t o metal which form an intermetallic c mpound i shown in Fig 2 The intermetallic compound ap pear in the pha e diagram a a vertical line and i i thi tru ture relati n hip may l e treated in the ame manner a a pure metal Tl e elements present in an intermetallic compound unite in definite atomic pr p rtion imilar to true chemical c m pound l ut unlike the chemical c mp und they d not f llow imple alence rule l ecau e all the metal ha e p iti e valences

In the lid luti n c pper nickel sy tem all the alloy of the vari u compositi n are of face-cen tered c l i stru ture and tl e lattice parameter a varie linearly with the atom concentrati n of the two c mp n nt from $a = 3\,6O\,kX$ f r c pper t $a = 3$ 1kX f r ni kel wh re k i a c n tant and X i tl at m n ntrati n

Th c l inati n f ni k l with magne ium re ult in tw interm talli mp und a sl n in Fig Th β pl a i f the pre t e t i l i m tr c mp und Ni Mg and th γ pha i precisel NiMg The tw n p n nt in thi y tem are f cl pa ked hexag nal str icture (Mg) and of fa -c nte f l l i tri ture (Ni) where f r xample in tl int rm talli c mpound (Ni Mg) tl t m ar l x g n lly arranged Tl inter at mi di tanc f r tl int rmetalli compound Ni Mg i 181kX wl r a th li tance f r Mg i

3.2028kX d for N 3.5167kX The intermetallic c mpou d th efo e differ co de ably n den s ty hardness trength ductil ty nd ther pr p erti s fr m the ompon t f om wh h they a e f rmed They ha e be om f e ide able te hn cal a d e t fic i te e t bec u e f the elatively h gh melti g po nt and ox d t on re tance of cer ta n int rm tallic compounds

I rec nt yes inte t h s c nt r d n inter metall c compounds f rmed of an el ment fr m gr p III of the p riodi table w th an elem nt of gr p V Comp und f thi type sh w sem c n duct ng pr pert e very imil r t th el mental emic nd t rs german um sil c n and gr v t n f gr up IV F r xample i di m a tim ny (I Sb) s ery milar to gray tin in its p pert es su h a lattice pac ng rag atomi we ght and the e f re d ity R cufication and tra i to ct o f t rm tall c mp nd f this typ ar of p mary import n e f m te hnol gical p nt of v w S ALLOY ALLOY STRUCTURES CERMET EQUILIBRIUM PHA E NO STOICHIOMETRIC COM POUNDS SEMICONDUCTOR SOLID-STATE CHEMISTRY [H H H]

B bl gr phy Am Soc Metal *M tal Ha d b ok* 1948

Intermolecular forces

Th n g ti grad e ts f the potenti l ene gy F between tw t ra t g mol l s, F being a func t n of th di t n R between th cent f the t molec les Th nt rm l c lar f c ar thus p l i in the reg o wh e F de e es th R (th reg n t the left f th m nimu n th ac mpa g figu) and ttr t wl e e F in c e e th R (th eg o to the right of th mi m m) Int mol c lar f a con en e tly d ded i t tw J hort r ge fo es a d l g ra ge f c s. The f rm a nfi d to eg f bo t 3 A the latt act b yond th t d t c

Short range forces In the figu th h rt g f es a e pul v Th s u ually the a f molec les wh h d n t i t a t ch m c lly Th teeply i g p rt f the rve n th or gi th n du to th l pp ng of l ct on cl ud a d

0 1 2 3 4A R

Ge ral h ract f f m l ule f urve

the fo ces which correspond t it are called ex chang force (a term exp e ng the mathemati al o igi of the force wh ch ari e mathematically from ertain xchange pr pe ties f the m lec ilar e ergy state funct on) Exchange f rces can al o be att act e Th s is the ca e for atoms which enter i t ch mi al combination The curve in the figu e then has a ery deep minimum at di t nces of the o der of 1 2 A from the orig n (for the mple t tom) Attracti e exchange for es are called vale ce fo c s and play an important r le thr ugh ut chemi try

Repuls ve xchange forces acc unt f r the me ch n al rig dity o *impenetrability* f m lecule the teepne s of th p tential energy c rve in the ex hange-fo ce d ma n gives r e to the l mited comp e bility of matter

Long range forces Long ra g intermolecular fo ce a e often called Van der Waal forces be cause th y lead to the Van der Waals equat o of tate (e VAN DER WAALS EQUATION) In particu l r the con t nt a i that equati n s m a ure of the r st ngth For une c ted nonpolar mole c l s th f rces e attr ctive These f rc give rise to a larg ariety of physical and ch m cal phe omen uch a urface te i n friction ha g s f pha e adhe ion and c hes on f liquid and olid sc sity diffus n th Joule Thom on effect a d th depa t res of ga s fr m the deal g s l w (irial coeff c nt) Van der Waal for es a e f om e l d ffe nt phys al cau es

O g The rig n of the Van d r Waal for es wa once sought in gra itat o l att a t s These a e n w kn wn to be much too m ll to ccou t f r th kn wn intermole ul r effe ts The first c n j tu (P Deby) in l ed the s umpt on th t n f the intera t ng m l ul ca a p rma e t multipol f r example, quadrupole a d ind es by electr c pol r zat n a m ll multipol n th ther Thi a tion k wn s the i duction Ef ct, wa hown to le d t attract e f rces Al though t does tak pla e many tanc s it i t o m ll to acc nt f th full tr ngth f th Van d Wa l fo es n ge r l

If b th mol ul have permane t p lar ty the m lt p les te d to al gn th m l es nd th eby gi e to attract e f ces This alignme t effect (W H Ke m) n mpo ta t part f th Van d r W al f es betw e pola m l ules b t d es t xpl th f r s b tween nonp la t u tu

The m g fact is f nd upo appl ati f quant m the ry to m lec lar i ter ctions It m y b de bed foll w in g l th el t on m l ul r l e ap dly and in a m ne unc el t d w th th l ct on c m t ns i oth r m l ule but wh n two m lecules re br ght fa ly l e t g th th l t o t ti fi ld t up by th m ng electr c n t i the m t ns n the tw m le l t b mo e or le s in pl e the ph agr me t be g clo the m lle th d t n e betwee i tera t g m l c les Att acti e f r s res lt, thes fo c b ng c ll d d pe

forces (F London) At large distance of epara tion the potential energy as ociated with disper sion forces is proportional to $-R^{-6}$

A further development of the theory hows that the interaction involves not only the interplay be tween the rapidly fluctuating dipoles con idered in the dispersion effect but al o the production of higher order multipoles (H Margenau) The e give rise to asymptotic interactions proportional to R^{-8} (dipole quadrupole interaction) R^{-1} (quadru pole quadrupole and dipole octupole interaction) and o forth

Only for symmetric molecules are the intermolec ular forces independent of the orientation of the molecular axes with respect to the line joining the molecules In general they di play feature which are not indicated in the figure They are functions of angles and therefore noncentral forces More over when more than two molecules interact the total potential energy of the sy tem is not nece sarily the um of the potential energies of all pairs Additivity in this en e holds only for the simpler kinds of di per ion forces Al o Van der Waals forces between molecules carrying permanent mul tipoles and between atoms or molecules in excited states can be repul ive as well as attractive

The relative role played by the different con tit uents of the Van der Waal forces is generally dif ficult to a es There are only a few in tances in which one type dominate all others In the ca e of H O at a di tance of eparation equal to the diameter of the molecule as given by kinetic the-ory the induction alignment and di per ion ef fect are all of comparable magnitude In the ca e of the di per ion forces the terms proportional to R R and R are of comparable importance

Shape of potential curve It is cu tomary to de ri e information concerning the parameter of the curve in the figure from c llective in e tigation of virial coefficient vi c itie cry tal energie and o forth Thi has led to the u e of emi empirical approximati n to the true interm lecu lar force curve Mo t widely u ed i the Lennard Jones potential which has the form

$$V = \frac{A}{R^{12}} - \frac{B}{R^{6}}$$

with proper choice of the c n tant A and B This eq iation has provided many u eful re ult The *intermolecular* potential curve ha al been suc ce fully calculated from fir t prin iple of quan tum mechanic but the c mplexity of the alcula tion ha re tricted the e eff rt to the simple t *molecule* *See* CHEMICAL BINDING MOLECULAR STRUCTURE AND SPECTRA QUANTUM THEORY NON RELATIVISTIC SOLUTION STATI TICAL MECHANICS VALENCE. [H M]

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Internal combustion engine

A prime mover the fuel for which i burned wi h the engine as contra ted to a team engine f r ex ample in which fuel i burned in a eparate f nace (*see* ENGINE) The mo t numerous of in ernal combu tion engines are the ga oline pi ton e gines u ed in pa enger automobile outboard en in for motor boat mall units for lawn m wers a d oth r such equipment as well as diesel engi used in truck tractor earth moving and imila equipment Thi article de cribe the e types of en-gines For other types of internal comb u ti n en gine *see* GAS TURBINE ROCKET ENGINE TUR BINE PROPULSION The pi ton engine u ed in aircraft is fundamentally the ame a that u ed in automobiles but is engineered for light wei ht a d is usually air cooled *See* AIRCRAFT ENGINE RECIP ROCATING

ENGINE TYPES

Characteristic features common to all comm r cially ucce ful internal combu tion engines in-clude (1) the compre ion of air (2) the rai i g of air temperature by the combu tion of fuel in thi air at its elevate l pre ure (3) the extracti n of work from the heated air by expan ion to the init l pre ure and (4) exhau t William Barnett first drew attention to the theoretical ad antages of combu tion under compre ion in 1838 In 1862 Beau de Rochas publi he l a treati e that empha ized the value of comb u tion under pre ure and a high ratio of expan ion for fuel econ my he pro po ed the four troke engine cycle a a mean of accompli hing the e condition in a pi t n engine (Fig 1) The engine require two revoluti n of the crank haft to complete one comb u ti n cycle The fir t engine to u e this cycle ucce fully wa built in 1876 by N A Otto (*see* OTTO CYCLE)

Two year later Sir Dougald Clerk d el ped the two troke engine ycle by which a similar c mbu tion cy le required only ne rev luti n of th crank haft In thi cycle exhau t port in the cyl inder were uncovered by the pi ton a it ap proache l the end of it power tr ke A e nd c l in l r then pumped a cl arg of air t the working cylinder through a check val e wh n the p mp pr *ure ex e de l tl at in the w rking cylinder*

In 1891 Jo ph Day impl if l the two-stroke en gine ycle by u ing the crank a e to pump th re qui ed air The c mpre i n troke of the w rking pi t n draw th fre h c mb u tible charge through a he k val e int the crankca and the next p wer troke of th pi t n c mpre es thi charge The pi t n unc r the exhau t p rt n ar the end of th pow r troke and lightly later unc er in take port opp it th m t a lmit th c mpres ed charge fr m the rank a A baffle i u ually pro id l on th pi t n h a l to l fl t th l arge up on d f th ylind r t a ng th remaining burned ga l wn th otl r si l a l out the ex hau t p rt *with a little mixing a p ible*

( ) fou roke-cycl po k g on g

(b) three-port type f two-cycl ng

Fig 1 ( ) The f t k f m de fo r t k n- g cy l F t k t k th t k l e (l ft) h op d d th p t m g d w w d d w g d go l p to th cyl d l m- p o t k th t k l h l sed a d th p to m g pw d mp g th m xtu O pow t k th g t y t m p d e o p k th t g t the m t A t b h gh p t d wh ch p h s th p t d w w d Fo h u t t k th e h u t l (ght) h p d d th p t n m g pw d f g th b ed g se f m the cyl d (b) Th m o t cc m pl h d w th t sep t of d a gl t t f th k h ft by th e-p rt two-cy le n- g e (F m M L. Smith a d K W St F l d C mb st McG w H ll 1952)

E g n u i g th two- t ke y le t day h be f rth mpl fied by u f third c l d r p rt wh h d p w th th r nk a heck l e ed by Day S h ngi es w de s f r mall u t wher f el e n my n t m port nt a mecha al mpl city a d l ght weight. Th y d t ed mecha ı ally ope at d al nd de lop ne mbu t n cycl p k h ft revo- l t n Nev rthel they d n t dev lop tw e the pow of f t ke cy l g w th the me ze w k g cy) de r th am n mb of o- lut pe m te (pm) Th pri ipal o s for th e (1) th ed t o n ffe t e cyl d r l me d e t the p t n m em nt qu ed t o th exh u t port ( ) the app ec bl m x ng l b ed (h t) ga w th the mbu ti bl mi t r nd (3) the l s f e m mb tibl m xt th o gh th exh t ports w th the b u t g se

Otto s engine l ke almo t all internal comb u t on eng nes developed at that per d burn d coal gas mixed in ombu tible proportions w th air pr or to be ng drawn into the cylinder The engi e load was ge erally controlled by thr ttl g the qu t ty f ch rg taken i to the cyli d r Igniti n was accompl hed by a de ce suc a an e ternal flam o an electric park s that the tim ng was c ntr llabl The e are e ential features of what has b c me known as the Ott o park ignition combu t n cycl

Ideal and actual combustion In the cla cal presentation of the f u tr ke cycle comb tion is ide l ed n tanta eous and at con tant v l ume Th simpl fies thermodyn m c analy is b it f rtunately c mb t on take t me f it is doubt f l if an e g n oul l un if th whole charge b rned det nated i ta tly Detonation of a small p t f the cha g n th yl nder fter mo t f th ch rg has bu ned p ogre i elv c u es the knock wh ch limits the c mp e on atio of an en g ne with g n fu l *See* COMBU STION KNOCK

The g s pr s e f n Ott combu t n cycle u g the fo r t k ngine cycle var es w th the p t n po t n as hown by the typ cal i d cator ard in F g 2*a* This i a co nt o al p s ure olume (*PV*) c d fo an 8 7 1 c mpre n rat o F r s mpli ty n alc l ti n of ng e pow r the a r ge et pr s ure d ring the work ng t oke c lled th m a ffecti e pre u e (*mep*) is fre- qu ntly d It m y be obt ned f m the average et h ght of the card which i f und l y meas e ment f th a ea with a pla meter nd by di ion of thi are hy its le gth Sim lar pressure lume d t may be plott d l garithmi coord at s as i *Fi b* wh h d el p e p n i n and c mpres- s n l ti a approx mately stra ght l es the sl pe f which how th v l e f exponent t u e i quations f r *PV* rel t o *hips*

Th roundi g of th pl ts at pe k pr s re w th the p ak de el p ng fter the p ton h s started its pow t oke en w th the pa k occurr ng b f re th pi t n rea hes the nd of the c mpre s o t ke due t tl e t m qui ed for combustion The tual t me requ red is more r le s under *on tr l f th ng e d sig* hec e h c n alter th d ign to v ry the i l e of th t rbule ce of th ha ge i the mp e i n pace p t and d r ng combu t The g ter tl e tu b l n tl e f t r th c mb sti a d the lower the a t k ock o ta e al e *req* ed f th fuel or the h gh th mpres on ati th t may be u ed with a g en fuel w th ut kn ck g (*s e* COMBUSTION CHAMBER COMPRESSION R TIO) On the the hand th turb l n e by the a d r t of p e sure r e wh h inc eases g ne rough es R *ghness* m t *n t ex eed* a level acceptable f a tom b le oth r s *r*

Effect of compression ratio Acco d g to l i al thermodyn mi theory th rmal effi e cy η of the Ott mbu t on cy le

forces (F London). At large distances of separation the potential energy associated with dispersion forces is proportional to $-R^{-6}$.

A further development of the theory shows that the interaction involves not only the interplay between the rapidly fluctuating dipoles considered in the dispersion effect, but also the production of higher-order multipoles (H. Margenau). These give rise to a symptotic interaction proportional to R (dipole-quadrupole interaction), R^{-1} (quadrupole-quadrupole and dipole-octupole interaction), and so forth.

Only for symmetric molecules are the intermolecular forces independent of the orientation of the molecular axes with respect to the line joining the molecules. In general they display features which are not indicated in the figure. They are functions of angles and therefore noncentral forces. Moreover, when more than two molecules interact, the total potential energy of the system is not necessarily the sum of the potential energies of all pairs. Additivity in this sense holds only for the simpler kinds of dispersion forces. Also, Van der Waals forces between molecules carrying permanent multipoles and between atoms or molecules in excited states can be repulsive as well as attractive.

The relative role played by the different constituents of the Van der Waals forces is generally difficult to assess. There are only a few instances in which one type dominates all others. In the case of H_2O at a distance of separation equal to the diameter of the molecules as given by kinetic theory, the induction, alignment, and dispersion effects are all of comparable magnitude. In the case of the dispersion forces, the terms proportional to R^{-6}, R, and R are of comparable importance.

Shape of potential curve. It is customary to derive information concerning the parameters of the curve in the figure from collective investigation of virial coefficients, viscosities, crystal energies, and so forth. This has led to the use of empirical approximation to the true intermolecular force curve. Most widely used is the Lennard-Jones potential which has the form

$$V = \frac{A}{R} - \frac{B}{R^6}$$

with proper choice of the constants A and B. This equation has provided many useful results. The intermolecular potential curve has also been successfully calculated from first principles of quantum mechanics, but the complexity of the calculation has restricted these efforts to the simplest molecules. See CHEMICAL BINDING; MOLECULAR STRUCTURE AND SPECTRA; QUANTUM THEORY, NONRELATIVISTIC; SOLUTION; STATISTICAL MECHANICS; VALENCY. [H. M.]

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Internal combustion engine

A prime mover the fuel for which is burned within the engine, as contrasted to a steam engine, for example, in which fuel is burned in a separate furnace (see ENGINE). The most numerous of internal combustion engines are the gasoline piston engines used in passenger automobiles, on board and outboard for motor boats, small units for lawn mowers and other such equipment, as well as diesel engines used in trucks, tractors, earth-moving and similar equipment. This article describes these types of engines. For other types of internal combustion engines, see GAS TURBINE; ROCKET ENGINE; TURBINE PROPULSION. The piston engine used in aircraft is fundamentally the same as that used in automobiles but is engineered for light weight and is usually air cooled. See AIRCRAFT ENGINE, RECIPROCATING.

ENGINE TYPES

Characteristic features common to all commercially successful internal combustion engines include (1) the compression of air, (2) the raising of air temperature by the combustion of fuel in this air at its elevated pressure, (3) the extraction of work from the heated air by expansion to the initial pressure, and (4) exhaust. William Barnett drew attention to the theoretical advantages of combustion under compression in 1838. In 1862 Beau de Rochas published a treatise that emphasized the value of combustion under pressure and a high ratio of expansion for fuel economy. He proposed the four-stroke engine cycle as a means of accomplishing these conditions in a piston engine (Fig. 1). The engine requires two revolutions of the crankshaft to complete one combustion cycle. The first engine to use this cycle successfully was built in 1876 by N. A. Otto (see OTTO CYCLE).

Two years later Sir Dugald Clerk developed the two-stroke engine cycle by which a similar combustion cycle required only one revolution of the crankshaft. In this cycle exhaust ports in the cylinder were uncovered by the piston as it approached the end of its power stroke. A second cylinder then pumped a charge of air to the working cylinder through a check valve when the pump pressure exceeded that in the working cylinder.

In 1891 Joseph Day simplified the two-stroke engine cycle by using the crankcase to pump the required air. The compression stroke of the working piston draws the fresh combustible charge through a check valve into the crankcase, and the next power stroke of the piston compresses this charge. The piston uncovers the exhaust ports near the end of the power stroke and slightly later uncovers intake ports opposite them to admit the compressed charge from the crankcase. A baffle is usually provided on the piston head to deflect the charge up one side of the cylinder to scavenge the remaining burned gases down the other side and out the exhaust ports with as little mixing as possible.

f at all with lo d pt vided th t the fuel air ratio remain constant and that the ignit on time is ad van ed at reduc d loads this c mpen ates for the slower ate of burning which re lts from d lution of th ombu t ble ch rge with th larger perc nt ages of bur ed ga e r ma ning in th combu tion pace

Effect of ignition timing Des g ers obtain high thermal eff ienc from h gh compre i n rat os at part lo ds whe e engines normally run at automo bil cru s ng peed w th optimum park ad ance but v id kn k on a a lable ga lines at wide open throttle by use of a reduced or comprom e p rk dv n Th tendency of an engine t knock at w de open throttle is reduced appreci bly wh n the park d an e r duced 5–10 from optimum as i f wn in F g 5 Advancing or reta d ng th park t ming fr m ptimum results in a cons tent l s i mep for any no mal engi as shown by the s l d urve The octane requ reme t fall rapidly as the spa k timing is ret rded the actual rate de p d ng n th natur of the ga oline as well as on the des gn of the combu tion chamber The dotted curv s A and B h w the ffects o a gi e ga li e of the e of mod rate and high tu bulence com bu tio chamb rs r spect v ly with the *same c m* pr sion ratio B cau e the mep c rve is r lat vely fl t ne r opt mum p rk adva ce retardi g the park for a 1–2° l s con de d normally ac ceptable n pract b c u of the appr ciable re du t on in o tan requ ement

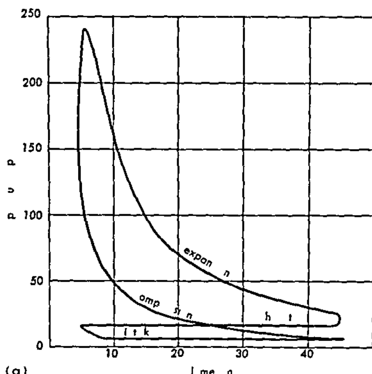
In F g 6 s mila data are sh wn by curve A for noth eng n w th mep pl tted di ectly again t *octa* req i ment as the park timing wa l rged Po nt ind c t s pt mum pa k t *ming* wh e 85 octan w r qui ed of the ga l ne to a o d k ock By rai g the compre sion rat o th p w r nd ta e *req rem nt* were also a ed as hown by th *dotted* urve B Although opt mum spa k qu d 95 t ne (p nt b) reta ding the sp k t mi g *and thus* edu ing the tan qu re m t t 86 (po t c) de eloped h htly *more* powe than with the *o g al* c mpre o rati t ts opt mum pa k d a e The ga n may be *neg* lig ble at w de op n th ttle b t at *lower l* ads whe k o k d s not d l *p* the pa k timing m y be d a ced to optimum (*p* int b) where appre bly m p w r m y b de elop d by th s me amou t f f l

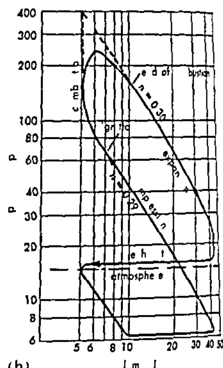
In addt n t th d ntages f the h gher c m p e s o at t crui i g loads w th ptim m park ad a ce the comp om sp rk t f ll load may be d a d t w d *pt m m s higher* octane f ls be om a a labl a d a c rre pond ng increa e in full th ottl m p njoy d Su h mp om se spark t m g h had m h t do w th th dopt on of mp n r t (f 10] f 13]

Effect of fuel air ratio A s milar l n of e s n ng how th t a f el *r mixture* ricl r than that wh h de el ps maximu n knock fre mep w ll pe m t u of higher c mp on r t os H w er th b fit d d f m omp om e or uperr ch mixt res v ry m h w th m tu e t mp r t

Fig 3 ( ) Eff ct f mp e n t o th m l ff cy a l l ted w th d ff t l f d mp ed with publ h d p m t l d t (b) l cr p w f m ng omp t o l c f t d w th = 1 3 P t g l but l ttl h d by d ff t l of

Fig 4 Ye -to-yea f l betw ve g m p t of d ve g oct mb f g l ld l h U d S t





Fg 2 (a) Typ cal pressu e volume ind cator card plotted on ectangular coordinat s (b) The same data plotted o loga ithm c coo d ates

$$\eta = 1 - \frac{1}{r^{n-1}} \qquad (1)$$

where the compression ratio r and expansion ratio r are the same ($r = r = r$) When theory assumes atmospheric air in the cylinder for extreme simplicity exponent n is 1 4 Efficiencies calculated on this basis are almost twice as high as measured efficiencies Logarithmic diagrams from experimental data show that n is about 1 3 Even with this value efficiencies achieved in practice are less than given by Eq (1) This is not surprising considering the differences found in practice and assumed in theory such as instantaneous combustion 100% volumetric efficiency and so on

Attempts to adju t classical theory to practice by use of variable specific heats and consideration of dissociation of the burning gases at high temperatures have shown that this exponent should vary with the fuel air mixture ratio and to some extent with the compression ratio G A Goodenough and J B Baker have shown that for an 8 1 compres ion ratio it should vary from about 1 28 for a stoichiometric (chemically correct) mixture to about 1 31 for a lean mixture Similar calculations by D R Pye showed that at a compression ratio of 5 1 n should be 1 ?58 for the stoichiometric mixture increasing with excess air (lean mixture) to about 1 3 for a 20% lean mixture and to 1 4 if extrapolated to 100% air Actual practice gives thermal efficiencies till lower than these which might well be expected because of the assumed instantaneous changes in cyclic pressure (during combustion and exhau t) and the disregard of heat losses to the cylinder walls These theoretical relations between compression ratio and thermal efficiency as well as some experimental results are shown in Fig 3 The data published by C F Kettering and D F Caris are about 85% and 82% respectively of the theoretical for the corresponding fuel air mixtures Figure 3b gives the theoretical percentage gain in indicated thermal efficiency or power from raising the compression of an engine calculated from Eq (1) with $n = 1\ 3$ These gains are less than half as great as those obtained by industry as indicated from the maximum brake mean effective pressure (bmep) values for production cars shown in Fig 4

Experimental data indicate that a change in compression ratio does not appreciably change the mechanical efficiency nor the volumetric efficiency of an engine Therefore any increase in thermal efficiency resulting from an increa e in compression ratio will be re ealed by a corresponding increase in torque or mep this is frequently of more practical importance to the engine designer than the actual efficiency increase which becomes an added bonus

Compression ratio and octane rating For years compression rati s of automobile engines have been as high a designers c nsidered pos ible with ut danger of too much cu t mer annoyance fr m detonation or knock with the ga oline on the market at the time (Fig 4) Engine de igners continue to ra se the compression ratios of their engines a rapidly as suital le ga olines me on the market

L ttle theoretical study has been gi en t the effect of eng ne load on indicated thermal efficiency Experimental evidence reveals that it aries little

H gh ntake a t mpe ture a d d ty mat ally a d c mbu t n in a d el eng ne, espec ally f fu ls ha g low v latil ty and h gh vi ity Som e gine h e not pe f rmed pr pe ly o h y fuel until pro ided with a sup r h rger The added c mpr s o f the p rcharger rai ed the temp at e and what i m r important, the d n s ty f th c mbu ti n air For an Ott engin an n a n e th the r temper ture or d n ty in r a es th t nd y f the engine to kn k and th r f re redu e the allow bl compr n rat o D el ngin s d elop inc ea gly high nd ated thermal effic ency t redu ed load be e f l ane fuel i rat s and rl r c toff Such mixtu e rati m y be lean tha will gn te n an Ott eng Furth rmore the redu tion of l ad i an Otto gine r qu res thr ttl g whi h de elops in rea ing p mp ng l s s in the intake ystem

TRENDS IN AUTOMOBILE ENGINES

E ch y r the powe developed pe cyl nde p k igniti a t mob le g e ha n re ed H ghe omp o t nd refi ed de ign a ount f r th n rea Cyli der d am t r in Am ri can made eng ne d c e ed ap dly at first as m pr m t w re trod ed and th n tabil d at about 3½ i (F g 7) In 1959 a e age American aut mob l e g e d am ter w 3 9 n Many Eu o pe n tom bil ng nes have cylind r bo e d me t r a m ll as 2¾ 2½ n

Bore stroke ratio E p r mental ng nes d ff r i g nly n bo e trok t show that th ti has app ec bl effect on f l eco omy nd fri ti at corr pond g p st sp eds. P a t al d a tage hi h r ult from a h rt tr k cl d (1) the gre t r rigid ty f crank haft f m the ho te a k che k with rankpi m tim s erlapp g m in l a ng a d (2) tl e n rrow r as w ll l ght yl der bl ck whi h is pos bl O the th r h d th h gher t f cr nk baft rot t on f r a equ ale t pi ton peed nece sitate great l e f r es nd eq e tronge l e pr ng Al th sm ll r depth f the compr s on p e f r a g e mp es n t nc ases the u fa to- l me ati d th p oport on f heat l t by r d at n during mb ti n Neve th l s, bore- t oke i h be n in eas g to more than 25 y rs and in 1959 reached 1 08 for the average autom bile in the Un ted States

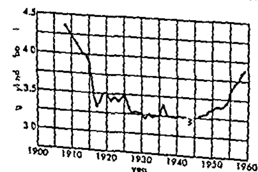


Fig 7 T d i ve g cyl d diam t f U ted St mob le g

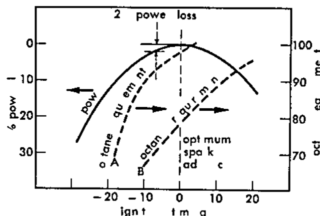
Compression ratio The cons derable increase n engine p wer h be n cau ed by steadily im pro ed d ign Compre i n rati and thus mep have inc ea d (Fig 8)

In 1959 mp es i n ratio of 10 1 er high r were pro ided on m e than 36% of all autom bile m del manufa tu ed Such rati s approach pract cal l m t mposed by phenomena other than deto n t on uch as preign tion rumble and other evi de s of nde irable combust on

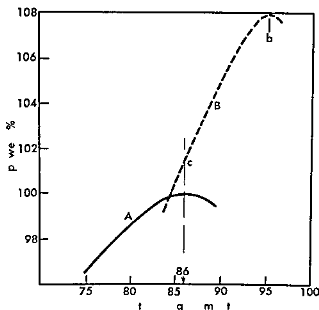
The modern trend toward h gh compre ion ra t with the r small c mpr ion volumes has dic tated the almost un er al u e of erhead al e in all new r Ame i an engine de gn High c mpres ion rati s al o t nd to restr t yl nd r d ameter be u e th lo ger flame tra el increa es the tend ency t knock (F g 9)

Improved breathing and exhaust Added power utput has be n b ught al o t by educing the pr sur drop n the intake system at high peed and by reduc g the b ck pres re of th exhau t system (F g 10) These r ults were a compli hed by larger lve a e s and al po t larger v n t ri r as a d by mor str aml ned m n folds La ge al ar as we e achie ed by highe l ft of the l es and by larger al es La g r venturi ar a in the ca bu etor were acl e ed by u e of one m e two- tage carburet s in the e s ffi i nt a r velo ity w devel ped t mete the fuel n one v ntu at low pow r the econd ventu was op ned f r h gh powe Better streaml ning f th manif ld pas ag betw en arburet r and val es, e pec ally at th cyl nder p ts, and th u e of dual exhausts nd muffl rs with r duced ba k p es u ha e l mp o ed engi e br athing and exh u t

Cylinder number and arrangement Engin power m y be rai ed by i r as ng tl number f yl nd rs a w ll s the p wer pe cyl nd r Th m nim m number of yl de s has g n rally been f ur fo f u cy l autom bil g n b c u th s is th mallest numbe th t p des r as abl b lance f r th ecip ocating p stons Many arly cars had fou -cylinder eng nes After 1912 ix-cyl nd r in l g n s b me p pul r They ha e superior balance f recip ocat g f c s and inde 90 V engine h d r n n popul ty until i bout eq alled the ix l n Aft r 1954 the V-8 d m ted th fi ld f r Ame an aut m b le en g es Th e are e e al important re ons f r this bes d tl e n sed power F r e mple th V-8 offe app ciably mo rigid con tru t on w th less be i g d flect on at high spe ds p ides m f m d t b t on f fuel to all cylinder from cent lly loc ted d wn draft ca bu to s d has h rt low ng ne th t fit. with n the hood d m ded by tyl t nds. Th olution f cyl nder arr g me t i luded f r a short pe od th V 12 nd e en a V 16 yl nd r de gn but experience h d that n th r d y th r w s too mu h pra



Fg 5 Effects of ad anc ng or etard ng ign t on tim ing from optimum on eng e powe and the result ng octane requ ement of the fu l in an e perim ntal en g w th a comb st on chamber having typ cal t rbu lence (A) and a h ghly tu b lent d gn (B) with the me comp on rat o Retard g the spark 7 for a 2% powe loss red ced the octane requirement from 98 to 93 for de gn A



Fg 6 Effect of a g compr s o t of a x pe m tal e g e on the powe o tput a d tan req me t at w de p th ottle Wh l a 86 ct f el was qu ed for opt mum sp k advance (ma m m p we) w th the o g al comp ess on r t o the same g sol wo ld be kno k f t th h gher comp ss o rat o by s t bly reta d g the gn t o t ming

and the sen ıtıvıty of the octane value of the par tıcular fuel to temperature that ıt ıs not generally practıcal to make much general use of thıs method Neverthele s ıt has been the practıce wıth p ston type aırcraft engınes to use fuel aır mıxture ratıos of 0 11 or even hıgher durıng take off ınstead of about 0 08 whıch normally develops maxımum mep ın the absence of knock

Compressıon ıgnıtıon engınes About 20 years after N A Otto first ran hıs engıne Dr Rudolf Dıesel uccessfully demonstrated an entırely dıffer ent method of ıgnıtıng fuel Aır ıs compressed to a pressure hıgh enough for the adıabatıc tempera ture to reach or exceed the ıgnıtıon temperature of the fuel Because thıs temperature ıs ın the order of 1000 F compressıon ratıos of 12 1 to 20 1 are used commercıally wıth compressıon pre sures generally over 600 psı Thıs engıne cycle requires the fuel to be ınjected after compres ıon at a tıme and rate suıtable to control the rate of combustıon.

Condıtıons for hıgh effıcıency The classıcal presentatıon of the dıesel engıne cycle assumes combustıon at constant pressure Lıke the Otto cy cle thermal effıcıency ıncrea es wıth compre ıon ratıo but ın addıtıon ıt varıes wıth the amount of heat added (at the constant pressure) up to the cutoff point where the pressure begıns to drop from adıabatıc expansıon *See* DIESEL CYCLE DIESEL EN GINE

Practıcal attaınments Dıesel engınes were hıghly developed ın Germany prıor to World War I and made an ımpressıve performance ın subma rınes Large experımental sıngle cylınder engınes were buılt ın several European countrıes wıth cyl ınder dıameters up to 1 meter As an example the two stroke Sulzer S100 sıngle actıng engıne wıth a bore of 1 meter and a stroke of 1 1 meters de el oped 2050 gross horsepower at 150 rpm Multıple cylınder engınes developıng 15 000 horsepower are ın marıne servıce Small dıe el engınes are ın wıde use also

Fuel ınjectıon In early dıesel engınes aır ın jectıon of the fuel was used to develop extremely fine atomızatıon and good dıstrıbutıon of the pray But the need for ınjectıon aır at pressures ın the order of 1500 psı requıred expensıve and bulky multıstage aır compressors and ıntercoolers

A sımpler fuel ınjectıon method was ıntroduced by James McKechnıe ın 1910 He atomızed the fuel as ıt entered the cylınder by use of hıgh oıl pre sure and suıtable spray nozzles After consıderable development ıt became possıble to atomıze the fuel suffıcıently to mınımıze the smoky exhaust whıch had been characterıstıc of the early solıd ınjectıon engınes By 1930 solıd or aırless ınjectıon had be come the generally accepted method of ınjectıng fuel ın dıesel engınes *See* FUEL INJECTION

Contrast between dıesel and Otto engınes There are many characterıstıcs of the dıesel engıne whıch are ın dırect contrast to tho e of the Otto en gıne The hıgher the compressıon ratıo of a d e el engıne the less the dıffıcultıes wıth ıgnıtıon tıme lag Too great an ıgnıtıon lag results ın a sudden and undesıred pressure rıse whıch causes an audı ble knock In contrast to an Otto engıne knock ın a dıesel engıne can be reduced by use of a fuel of hıgher cetane numbe whıch ıs equı alent to a lower octane number *See* CETANE NUMBER COM BUSTION WAVE MEASUREMENT OCTANE NUMBER

The larger the cylınder dıameter of a dıe el en gıne the mpler the devel pment of good combu tıon In contrast the maller the cylınder dıameter of the Ott engıne the le the l m tatı n from det on tı f the fuel

t cal d ffi ulty in pr ding g od man f ld distribu ti n of fuel e pec ally when t t ng cold nd too mu h d ffic lty in keepi g ll spark plug fir g *See* AUTOMOBILE

Engine balance Rotating ma ses su h a crank p ns nd the low r h lf of a c nnecting od may be c nte bal n d by w ght atta hed t th crank h ft. Th v br t on wh ch would re ult fr m the ecip ocating for e of th pi t n a d the r a o-ci ted ma s is u ally m nim z d or elim nat d by the a rang me t of cylind rs in a mult cyli der e g ne so th t the re ip ocat ng f c s in on cyl de r n utr lized by tho e in an th r Whe th e forc s re in d ffere t pl nes a co e pond ng p i of yl nd s i required t ounte a t the e lt ng rock ng upl

If p t n m t n w re truly harmoni which w uld r qu a c n ect ng r d of infin te length the r c p ocati g rti f c at ea h e d of th strok w uld be

$$F = 0\,000456WN\,s \qquad (2)$$

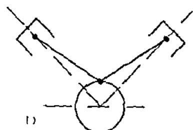
he W s the t tal we ght of th r e p o at ng p t in e cyl nd r N i the pm a d S th tr ke i in h s Both F and W a e in pou d B t th p t n m t n i n t mpl ha mon c b c the c n t g r d i n t nfin te n l gth and th pi t n t a ls m e th n half t tr k wh n the ankp t rn 90 f m firing d ad cente Th s di t t n of th tru harm n mot on du t the o-c ll d ngul ty a of th onnect ng od

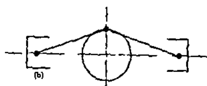
$$= {}_{l} = \frac{s}{2l} \qquad (3)$$

h r i the c a k rad the t oke a d l the ect ng od le gth ll i n h

Rec p o t ng e ti f a t n l with the yl nd is d may b id red a c mb a ti f a pr mary f rce—th t e h rmon c f e f m Eq (2)—o c ll t n t th ame frequ cy a th k h ft pm a d nd ry force c l l ting at tw th f q n y h ing a al e of Fa wh h i dded t the p mary t fi g d d c t r d bt a t d f m t t n r d ad ce t r l e l t the a i fi t b t p dly d m i h g seri of eve harm n cs at 4 6 8 t m nk h ft p ed b t b the d h rmoni th y r so mall th t they m ge ally b neg lected Th s f r ecting d w th the er ge g la ty f the 1959 r m b l e g whe $a = 0.269$ the nert a f ce used by p t n t fi ng d d e t t bo t l 7 t mes the pu bar m n f and t i d d nt r t 0 73 t m l g

Wh tw pi to s act on ne c a kp n with the l d 90 V r g me t in F g 11 th res lts t p m ry f e r rad l d f con st m gn t d a d tates a u d th c ank h ft w th th kp Th f t m y be ompen ted f by a dd ti n t th we ght q i d t co t b l th ce trifugal fo f th evol i g kp d t a soc ted m es Th ult





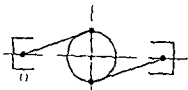


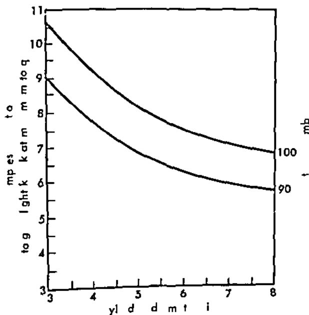


Fig 11 A g m ts f two cyl d rs ( ) 90 V f m t w th c t g d p t g n th m kp n (b) opp ed cyl d w th n e t g od p t g th me c k p n ( ) pp ed cyl d rs w th p t n p at g n a k p 180 ap rt (d) d uble-opp ed p t th sam cyl d but pe t g sepa t k h ft

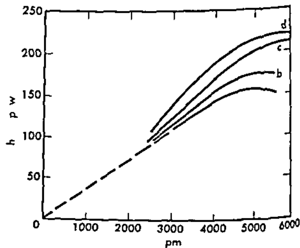
a t f the co dary f r f the tw p ton 1 41 times l rg s for n cyli der a d ecip o-cat a ho zont l plane th ough the r nk haft at twi e cr nkshaft spe d

I n i w th oppo ed ylind s if the two o n ting r d ope te th am rankp n a in Fig 11b the pr ma y f rc a e added and a e tw ce a great as for o p t n but the nd ry fo c s c n l If th p t ns pe te on tw crank pi 180 apart a n Fig 11 all rec pro at ng fo c re bal n ed H w e a th y will be n d ff re t pl n o ki g c uple w ll d elop n le s c mpe sated by an opp s g couple f om an oth r pa of cyl nde D uble ppo d pi to p i p r t ng a ngle ylind n tw cr nk haft s in F 11d (with a r s shaft t mai t i ynch m) re i p fe t balan e for pri mary and econd ry procat g for es as w ll a fo r t ti g ma es a d to que ea tio s

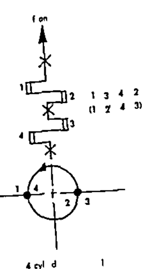
F g 8 Trend n compres on rat o mea effect v pressu e and power of ave age Un ted St te a tomo bile g nes

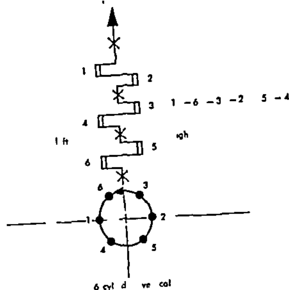


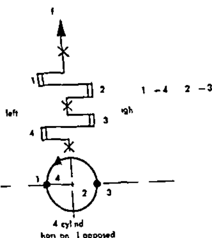
F g 9 Rel tion between cyl nde d ameter a d l m t ng compre s o r t o for e g es of s m la des g w th 90- a d 100-octane gasol s

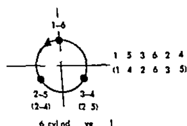


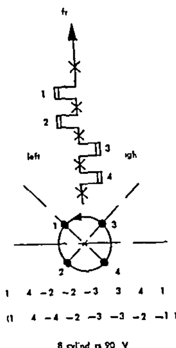
F g 10 I c a e I the p k pow f a s -cyl nd ng (210 In d plac m nt) by s c ss e reduc t o i the i ta c t a flow th ugh it C rve a pow d loped by o g I e g e w th two 1¾ ca b t v b h ghe al e l ft v l s nd d l e hau t sy t m cu e c la ger v l smoother alve po ts a d two 2 in a b to s c rv d th e dou bl b l a bu et











12 Typ l cyl d rr g m ts d fi g d rs

i t pe It h th d d t g how f i g m e t m t e h rm l m f ld npe t nles the w t pply f m th yl l h d h rt ted th gh th m f ld k t by t bl wat th rm t t d g m p

O f th d tage f th V 8 g e i the ll t t k m f ld d g perm tted by th ent lly loc t d l t w th b t m ll d ff es th l gth f th p ag betw th b t nd h yl der d q l mbe f ght gl be d h i typ l i t ke

m f ld i g d l carb ret r (Fig 14) With the u al fir g o der h wn in Fig 12, the firing interval for e ch f the l wer b che (sh wn d tt d) ev ly p ed 360 k h ft degrees part, b t fo h f the pp b he two cyl d fi 180 d then 540 p rt

Ici g Be g l e ha d ble l te t h t f po izat t l we the a t mpe atu e a it evapo t s. Th s tru even at the low t m p r t es whe e ly mall part f it i por zed It ther f p bl f m t e wh h may be c rr d by th a to f ez und ert c ndi

In the conventional four cylinder in line engines with crankpins in the same plane the primary reciprocating forces of the two inner pistons (2 and 3) cancel those of the two outer pistons (1 and 4) but the secondary forces from all pistons are added They are thus equivalent to the force resulting from a weight about $4a$ times the weight of one piston and its share of the connecting rod oscillating parallel to the piston movement having the same stroke but moving at twice the frequency A large a for this type of engine is advantageous Where the four cylinders are arranged alternately on each side of a similar crank shaft and in the same plane both primary and secondary forces are in balance Six cylinders in line also balance both primary and secondary forces

Early eight cylinder 90 engines with four crank pins in the same plane like those of the early four cylinder engine had unbalanced horizontal secondary forces acting through the crankshafts which were four times as large as those from one pair of cylinders

In 1927 Cadillac introduced a crank arrangement for its V-8 engine with the crankpins in two planes 90 apart Staggering the 1 and 2 crankpins 90 from each other equalizes secondary forces but the forces are in different plane The couple thus introduced is cancelled by an opposite couple from the pistons operating on crank pins 3 and 4 This arrangement of crankpins is now universally used on V-8 engines

Torsion dampers In addition to vibrational forces from rotating and reciprocating masses vibration may develop in an engine from torsional resonance of the crank shaft at various critical speed The longer the shaft for given bearing diameter the lower the speeds at which the vibration may develop Such vibrations are dampened on most six and eight-cylinder engines by a vibration damper which is similar to a small flywheel on the crank shaft at the end opposite to the main flywheel but coupled to the shaft only through rubber so arranged as to reduce the torsional resonances Such vibration dampers are usually combined with the pulley driving the cooling fan and generator *See* MECHANICAL VIBRATION

Even though the majority of American automobile engines are now dynamically balanced it has been general practice for several years to mount them in the chassis frame on rubber block This reduces the transmission *of the small amplitude* high frequency vibrations in torque reaction as well as small unbalance of reciprocating part in individual cylinder so that a low noise level is developed in the car from the operation of the engine

Firing order Cylinder arrangements are generally selected for even firing intervals and torque impulse as well as for balance As a result the cylinder arrangements and firing order shown in Fig 12 may be found in automobile use It is generally customary to identify cylinder banks as left or right as seen from the driver s seat and to number the crankpins from front to rear Manufacturers do not agree on methods of numbering individual *cylinders of V type engines However th[illegible]* [illegible]ments and firing orders shown are in general [illegible] with the addition in parentheses of alterna[illegible] arrangements only occasionally used.

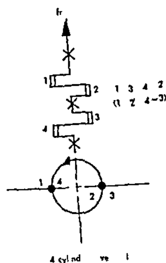
Intake manifolds Intake manifolds for m[illegible] cylinder engines should meet several requirements for the satisfactory performance of spark ign[illegible] engines They should (1) distribute fuel equally to all cylinders at temperatures where un[illegible] fuel is present, as when starting a cold engine or during the warm up period (2) supply sufficient heat to vaporize the liquid fuel from the carburetor as soon after starting as possible (3) distribute the vaporized fuel air mixture evenly to all cylinders during normal operation and at low speeds (4) offer minimum restriction to the mixture flow at high power and (5) provide eq[illegible] ram or dynamic boost to volumetric efficiency of all cylinders at some desired part of the engine speed range

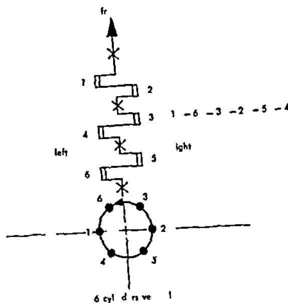
Experience shows that the passages between the carburetor and each cylinder should be nearly equal in length with the same number of right angl[illegible] bends and that no cylinder should be siamesed with another at the end of a leg of the manifold, particularly if the firing intervals for these cylinders are uneven Passage length affects the amount of boost in volumetric efficiency or mep and the speed at which it peaks (Fig 13)

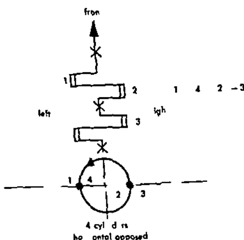
For the warming up period with liquid fuel present rectangular sections are desirable to impede spiraling of liquid fuel along the wall and right angle bends should be sharp at least at their inner corner so as to throw the liquid flowing along th[illegible] inner wall back into the air stream.

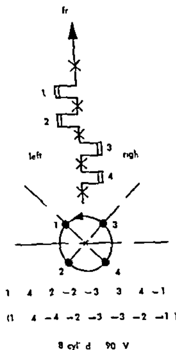
Manifold heat Intake manifold of most American automobile engines are heated to the temperature required to vaporize the fuel from the carburetor (120–140 F) by exhaust gas passing through suitable passages in the manifold casting particularly at the first T beyond the carbure[illegible] *where th[illegible]* liquid fuel impinges before turning to side branches To speed the warm up process thermostatically operated valves are generally placed in the engine exhaust system so as to force most of the exhaust gases through the intake manifold heater passages when the engine is cold After the intake manifold h[illegible] reached the desired temperature such valves *are intended to open and permit only the neces[illegible]* small portion of exhaust gases to continue passing through the heater This is an important feature for too much heat causes a loss of engine power and aggravate the tendency for the engine toward knock and vapor lock

On some engines the intake manifold are heated by water jacket taking hot water from the engine cooling system This gives uniform heating over a wide range of operating conditions without danger of the [illegible]e heating that might result from exhau[illegible] g[illegible] heat if the thermostatic exhaust valve shoul[illegible]









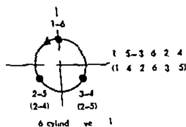
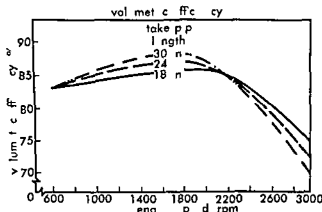


Fig 12 Typ l cyl d rra g m ts d fi g d

f l t re It ha th d s d ant ge h wev r of q g m t m t re h no mal m fold t mpe t r l th wat pply f m th cyl d h d hort u ted th gh th m f ld ı k t by t bl w t the m st t d r ng w rm p

O f th d t g f the V-8 e g th ll nt t k m f ld d gn p rm tted by th entr lly loc ted b r t w th b t mall d ff es th l ngths f th p g betwee the a b t d h yl d d an qu l mbe l ght gl be d ı h a typ c l ntake m n f ld us g du l a bu et r (F g 14) W th the ual fi g d shown Fig 12 the fi ng ı t rvals fo each of the low bra hes (h w d tted) e e ly p ed 360 cra k haft degrees ap rt b t for e h f the pp r b an h s tw cylin de fire 180 d then 540 part

Icı g Be au e g l ha c ns d bl l te ı h t of po t t l wers the a t mp t ıt e p t Th ı true n at th l w t m p tu wh e nly mall part f t p z d It ıs th ef e p bl f m ı t wh ch m y be c ed by th a r t fr eze u de rt n cond

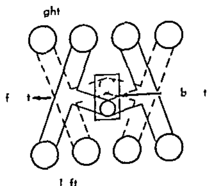


Fg 13 Effect of intake p pe length on the volumetr c effc e cy of a single cylinder e gine at d fferent en gine speeds

tions Ice is most likely to form when the atmos phere is almost saturated with moisture at tem peratures slightly above freezing and up to about 40 F When ice forms around or near the throttle it can seriously interfere with the operation of an engine For this reason small passages have been provided on some engines for jacket water or ex haust gas from the heating supply for the intake manifold to warm at least the flange of the carbu retor Here again too much heat would produce vapor lock and this would interfere with normal fuel metering

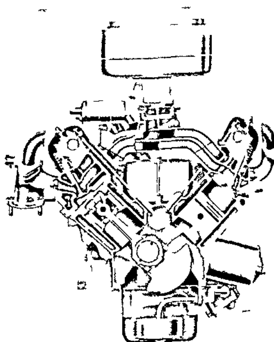
Typical American automobile engine The typ ical automobile engine as manufactured in the United States during 1959 was an eight cylinder 90 V with overhead valves such as shown in Fig 15 The cylinder blocks and upper crankcase are cast in one piece The structure has sufficient ri gidity to permit high speeds (4400–5000 rpm at maximum power) without serious deflections Crank haft stiffness is aided by a main bearing between each pair of opposing cylinder which have their connecting rods taggered side by side on the same crankpin

The V arrangement makes possible efficient in take manifold design with symmetrical and almost equal passages to each cylinder from a centrally located down draft carburetor It is short and low important characteristics for the styling of the



Fg 14 Typ cal i take man fold with d l ca b tor on a V 8 ng e

cars in which it is used It is water cooled under pressure limited to 7–14 p i by a spring loaded radiator cap and it has water jackets completely surrounding each cylinder for the full length of the cylinder barrels Valves are operated by a single camshaft in the V which is driven by a silent chain. Over 70% of the engines quiet the valve action by hydraulic lifters (*see* HYDRAULIC VALVE LIFTER) Almost as many engine designs provide means of rotating at least the exhaust valves during engine operation and some rotate the intake valves also. This distributes wear and improves valve life It is standard practice to provide two narrow compre sion and one oil scraper ring on each pi ton abo the wri t pin About half the de igns lock th wrist pin in the connecting rod the remainde leave the pin free to rotate All compre ion ring are of cast iron about 0 078 in wide and have wear resisting coatings Top rings are generally chrome



Fg 15 Typ c l mode V 8 automob le eng ne w o e h d v l s (Fo d M t Co)

plated although one manufacturer uses tin plati Most lower compression rings are tin plated some ha e coatings of phosphate or oxide scraper rings are about 3/16 in wide and m of cast iron or chrome plated steel The average d mensions of various engine parts are gi en in the table

FUEL CONSUMPTION AND SUPERCHARGING

Fuel consumption at loads throughout the operat ing range of an engine provide insight into such characteristics as friction loss within the engine Volumetric efficiency of an engine can be increased by use of supercharging

Part load fuel economy When the fuel con sumpti n of a spark ignition engine at a given fuel air ratio is plotted against brake hor epower

ag engi d men ion (i l ches)
1959 automob l s

	4 0
Cyl d bore	3 46
Strok	6 44
Co ectı g rod l gth	0 69
R t f cra k d t l gth	8
Co ectı g rod b g-e d be rı g d m t	0 84
Co ectı g rod b g-e d bearı g w dth	1 9
Co ect g rod b g-e d bearı g	0 99
Wrıt p d m t	63
M be g d m t	0 89
M be rı g l gth	34
M be ıng	1 90
I tak l h d d m t	1 56
Exh ust l h d d m t	

tr ıght l ne m y ge rally be dr wn th ough the te t p nts at g n peed as h wn n Fı 16 pr ded that th test r run w th opt mum pa k d a ces. S h l e r mıla to the Wıll ns lines l g u d f r the ste m on umpt o of t am en g nes

Fo p act cal p p s th l n s at r o s peed m y be c s d r d p r ll l r a w d ra g f pe d Wh n ext p lat d to z r fuel e n mpt the n gat pow r ad gs may be co de d a th fr t o p we abso b d t the re p nd g peeds. O ch o d ate lı e rad tı g f m th ıg p e e t c n t nt r to f f l c n umed t p wer developed nd th r f r c tant pecific fu l c n umptı n (f) Seve al ch l e a e ı d c t d al ı Fıg 16 f m wh ch th f at r l ads m y b d d r ctly wh e th y c the p rf rmance l nes at the ar ous p ed

S mıl r pl ts of even gr ater ut l ty may b d d c ted ho epowe ba s s h bee d e Fıg 17 f r the me dat F ma y g es s gl pe fo ma l n m y be d wn th gh all te t p ts t g en f el aı r tı r a c ıd rabl a ge f peed When t p l t d the p f rm e l p es th gh th rıgı t doe f the gı h w F g 17 th ındı ted f a d thermal effi e y of the g rema c n

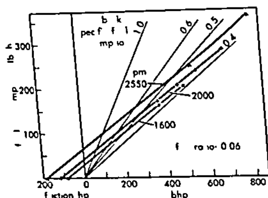


Fıg 16 F l mptı f gl t p rt load pl d typıc l W ll l g t b k h rse-pow Do w t k w th pt m m p k d d w h f l-a t dı t d t h t t p t

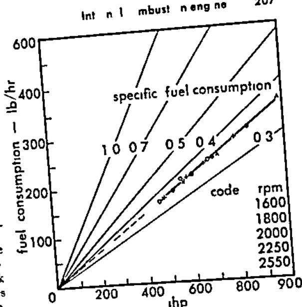


Fıg 17 The d t f F g 16 pl tt d ag ı t ı d t d h p w by wh h th d ff c f p ed a t l d

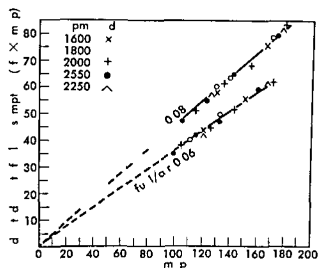
sta t o er the l d rang e ed Frequently a pe form nc l ne for n eng e pa es a l ttle to the l ft of th rıgın beca of ndıt on cau ıng a d c ea ın th rmal effic en y as the load ı e d ced uch s sufficıe t turbulenc r t o low a man fold l ıty For a mo e complete pıctu e of the f el c sumptıo perfo ma ce of an e gı e s mıl r plot m y be made n an mep b ıs Whe th d e and b th fuel c nsumptı n a d ho e powe a d ıded by the g ne factor whı h con erts h ep we to mep the sl pe nd nat r f the f el p rf rm c lın r ma unch ged The fuel s mpt on c l th n b c mes q val nt to the p d t f m p a d sfc S h plot may be on the ba f e th ınd c t d m p (mep) b ak m p (bm p) Fıgu 18 sh ws th me data F g 16 d 17 plotted an mep ba ı for two d ffere t fuel r tı s

The f l umptıon perf rm n of d e el g s t part load may b hown on m lar ba es b t th plot ho ld not b exp ted t be t ght b ca th ffect fuel r at arıes w th lo d Th s ıll trated F g 19 It ı haracte tıc of m t d e l ngın that th c rv t e of th plot g e lly flatt t at l w loads that ıt be come t mpt g t e trap l t ıt to ze fuel c n mptıo If th the mal ffic e cy mp o es w th red ct f l d ıt would theory f th l cal d esel y l b cau e f th educed cut ff th ı te c pt w ll be t the ght f th orıgın when pl tt d n a ımep b If pl tted n bm p b ıt wo ld be t th r ght f th tru mea u ed frıct n m p It th f n t f t t m t th f ıctıo of a d esel engıne by th method l n d t m urements are a a lable d r gh pp m t n t f ctory Alth gh the e f el con umptı n pe f rm e plot f

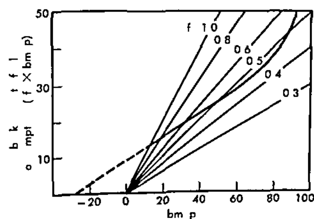
considerable utility for recording such data for an engine the fact that they are curved requires at least three or even more points to fix their location on the plot

Supercharging spark engines Volumetric efficiency and thus the mep of a four stroke spark ignition engine may be increased over a part or the whole speed range by supplying air to the engine intake at higher than atmospheric pressure This is usually accomplished by a centrifugal or rotary pump The indicated power of an engine increases directly with the absolute pressure in the intake manifold Because fuel consumption increases at the same rate the indicated sfc is generally not altered appreciably by supercharging

The three principal reasons for supercharging four cycle spark ignition engines are (1) to lessen the tapering off of mep at higher engine speed (2) to prevent loss of power due to diminished atmospheric density as when an airplane (with



Fg 18 The f l con umpt on data of Fg 17 plotted o the bas s f m p by d v d ng the f el le a d th power scale by th am f t (k = ihp/mep) A l for 0 08 fuel air rat o has been add d to show the eff ct of f el a r rat o o the slope of such plots



Fg 19 F el co s mpt n of a d es l e g at part loads showi g th urvature typ c l of h engi e on the e c o d ates d e to Inc ea ng ffect s of f el-a r rat o as the l ads are nc ea d

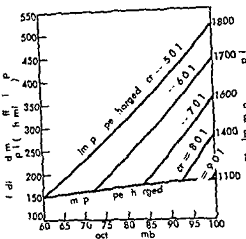
piston engines) climbs to high altitudes and (3) to develop more torque at all speeds The e will be discussed in greater detail

In a normal engine characteristic torque rises a speed increases but falls off at higher speeds because of the throttling effects of such parts of the fuel intake system as valves and carburetors If a supercharger is installed so as to maintain the volumetric efficiency at the higher speed without increasing it in the middle speed range peak horsepower can be increased with little if any increase in octane requirement

The rapid fall of atmospheric pressure at increased altitudes causes a corresponding decrease in the power of unsupercharged piston type aircraft engines For example at 20 000 ft the air density and thus the absolute manifold pressure and indicated torque of an aircraft engine would be only about half as great as at sea level The useful power developed would be still less becau e of the friction and other mechanical power lo es which are not affected appreciably by volumetric efficiency By the use of superchargers which are usually of the centrifugal type sea level air den ity may be maintained in the intake manifold up to considerable altitudes Some aircraft engines dri e these supercharger through gearing which may be changed in flight from about 6 5 to 8 5 times engine speed The speed change avoids oversupercharging at medium altitudes with corresponding power lo s. Supercharged aircraft engines must be throttled at sea level to avoid damage from detonation or excessive overheating caused by the high mep which would otherwise be developed *See* SUPERCHARGER

Normally an engine is designed with the highest compression ratio allowable without knock from the fuel expected to be used This is desirable for the highest attainable mep and fuel economy from an atmospheric air supply Any increase in the volumetric efficiency of such an engine would cause it to knock unless a fuel of higher octane number were used or the compression ratio were lowered When the compression ratio is lowered the knock limited mep may be raised appreciably by supercharging but at the expen e of lowered thermal efficiency There are engine uses where power is more important than fuel economy and supercharging becomes a solution The principle involved is illustrated in Fig 20 for a given engine With no supercharge this engine when using 93 octane fuel developed an imep of 180 psi at the borderline of knock at 8 1 compression ratio If the compression ratio were lowered to 7 1 the mep could be raised by supercharging along the 7 1 curve to 275 imep before it would be kn ck limited by the same fuel With a 5 1 ompres ion ratio it c uld be rai ed to 435 imep Thu the imep cou ld be rai ed until the cylinder became thermally limited by the temperatures of critical parts particularly of the pi ton head

Supercharged diesel engines Combusti n in a four str ke die el engine is materially improved by



Fg 20 R I t h p b twe omp t o d k k I mited m p f g ct mb b- to ed by pe ha g g l bo t ry g e

upe cha g g In f ct f els wh h would sm ke b dly and m sfi e t l w load w ll b n otherwise t sfacto ly w th s per ha g g The imep s d rectly with th up r harge pre ure nt l it s l m ted by th rate f h at flow f m the met l p rts surro nd ng the mb stion hamber and th r

It g tempe atu e A pra tical appl c tion of th l mit t on wa mad n a loc moti built by th Br t h Ra lways whe e th p wers and thus the h t dev loped we held r a n bly const nt ove a id rabl peed rang by d i ng the u pe ha g r t n tant peed by it wn eng I th w v th pe ha ge pr r a ied n rsely with th pe d f th m i e g The c rre p d g t rqu r se at ed d p ed d p n ed with m h g ar hifting wh h would ha been re- qui d du g a l r ti n w th a con nt l en g n

Wh s pe h g f the th cent if g l r po t e d pla m nt typ are dr en me h n ally by the eng the powe eq ed b mes n addi t l l t the ng o tput Exp n e h w th t th r d g e of upe h rg f y eng ne h h dev l p ma m m effi e cy too high a pe h g b b m e pow r th uper h g th g n d l y th eng ne pe lly t l w l ads A ther m of d ng the up r h rg wh h b m g q t gen l by h t t b wh h r m f th ergy th t ld th w be wa ted n the ng n ex h t Th ma be e mpl hed w th m ll n f b k p es r th t l ttle p w l st b th eng Th type f d e es lts n pp er bl r ffi ie v t lo d h gh gh t dev l p th ece ary xh t pr pe l g g two-cy l desel g n requ m m f es t ng th ttl g th exh u t d t t ld up yl d p e t the tart f th mp es trok nd i used o a f w larg g es M t med ma d l rge two-cy l l sel en g es ll l pped w th bl w to a ng

th cylinder after th w rking strokes and to up- ply the air requ red for the ub eque t cycles The e blowe s n cont a t to supe charge s do not build up app ciable p essu e n the cylinder at the tart f c mpre i n If the capac ty f such a blower is gr te tha the engi di plac ment it will scav nge th cyl der f practic lly all exhaust prod uct even to the extent of blow ng some a r o t thro gh the exhau t ports Such bl wers l ke super charger may be mech n cally dr en by the engine or by exh ust t bi es [N M]

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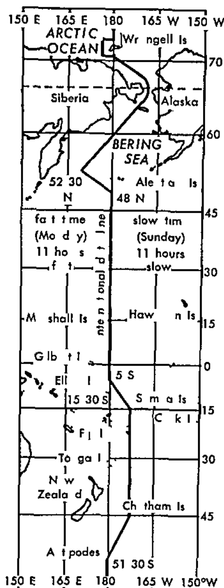
Internal energy

A ha acteri tic pr perty f the tate of a thermo- dynam c syst m ntroduced n the fi st law of ther modynam s For a static closed sy tem (no bulk moti n n transfe of matter acr s its b unda r es) th hang ΔE n i te n l energy for a p oc es is q al to the he t Q ab o b d by the system f m t u r u di g m n s th work w d ne by th y t m on its ur ound ngs O ly a change in nternal en gy ca be mea ured n t its alue f r ny ingl st t For a g i pr ce s the ch nge n ntern l ene gy i fix d by the in tial nd final states nd is i d pendent of th path by which the cha ge n tate s ac mpl hed

Th ternal e ergy in lud s the ntrin ic en e gi s of the ind idual mol cule f which the sy t m i mpo d a d ontributio s from the n tera ti n am ng them It does not includ e ntri b t on f om the potent al e e gy o kinetic en ergy of the sy tem a a whole th changes mu t b a counted f r expl c tly n the t e tm nt of fl w ystem Becau e t mor c n n ent to use a an ndepe d nt i bl (the p es ure P fo the sys tem nstead of its l me V) th wo king equa ti ns f pra t l thermodynam c a us ally writ t n n t rms f uch f nct o s as the enthalpy $H = E + PV$ nste d of the int rnal energy itself Se ENTHALPY THERMODYNAM ICS (CHEM ICAL) [P B]

International Date Line

The 180 me dian where ach day offic lly b gi a d end A a pe on tra ls e stwa d gai t the appa e t m eme t of the un be g ns l ho for eve y 15 f l ng tud a h t a el we tward be l e t me at the m ate Two pe ple tart ng f m y m d n a d trav l ng r und the world in opp te d ection would ha e the s m time when th y me t, but wo ld be l day ap rt date If th w e n nternati n l agreement a to whe h d y h ld b gin nd e d th uld be y numb r of pl s de gnated To l mi



Th Intern t onal Date L

Conference in 1884 designated the 180 meridian as the location for the beginning of each day Thus when a traveler goes west across the line he loses a day if it is Monday to the east it will be Tuesday immediately as he crosses the International Date Line In traveling eastward he gains a day if it is Monday to the west of the line it will be Sunday immediately after he cros es the line

An interesting example can be taken from condi tions now nearly attainable with jet aircraft If one could board such a plane say at noon in Washing ton D C and fly westward at that latitude around the world to return in 24 hours the rate would match the rotation of the earth Although con stantly under the noontime sun this traveler would need to adjust his calendar one day ahead upon crossing the International Date Line because he would arri e in Washington at noon 24 hours after embarking Thus his calendar day would agree with that of the Wa hingtonians

The 180 meridian is ideal for serving a tl e In ternational Date Line It is exactly halfway arou d the world from the zero or Greenwich meridian from which all longitude is reckoned It al-o fall almo t in the center of the large t ocean conse quently there is the least amount of inconvenience as regards population centers A few deviations in the alinement have been made such as swinging the line east around Siberia to keep that area all in the same day and westward around the Aleutian I lands so that they will be within the ame day a the rest of Alaska Other minor variations for the same purpose have been made near the Fiji I lands in the South Pacific See GEOGRAPHY MATHEMAT ICAL [V H E]

Interplanetary propulsion

Powered flight between planets The sy tems u ed for interplanetary propulsion must provide the ac celeration to propel a flight vehicle and to maneu ver it along its trajectory High acceleration is desirable for near space flights and chemical rock ets seem most appropriate Moderate acceleration is adequate for trips to the inner part of the olar system Low acceleration during the long times for flights to planets beyond Mars will produce accept able velocities for such flights electrical propul sion systems eem uniquely qualified In add t on to the midcourse propulsion systems the vehicl or its detachable booster may use other propul i n means for launching landing and operating in the regions of strong planetary gravitational fields (see ROCKET STAGING)

Engine types Several basic propul ion tech niques have been considered for interplanetary pro pulsion Two are rockets in the strict sen e that they carry and heat their own fuel and expul i e material (see ROCKET) These are the chemical rocket and the nuclear rocket The other techniques rely on solar energy or carry their own eparate energy source they are the olar heating rocket photon propulsor and electrical propul or

Chemical rocket The nature of the propellant whether solid or liquid provides the ba is for classifying chemical rockets (see PROPELLANT) Both types convert chemical energy into thermal energy of a working fluid by combustion and con vert the thermal energy into kinetic energy in a nozzle expelling the working fluid at high velocity to pro ide forward thrust See ROCKET ENGINE

A s lid propellant rocket once ignited normally burns until all its fuel is consumed The shutting down and restarting of a liquid propellant rocket is feasible but requires special techniques A low pre sure monopr pellant rocket is more ea ily re started but de elops lower performance (see SPE CIFIC IMPULSE) A monopropellant rocket develop a specific impulse f 200–225 ec compared with a theoretical lim t of 440 ec for a high energy bipro pellant

Nucl a pr pulsi n Three type of nuclear r cket are under study In the fi sion type ura nium in a sol d reactor he t a w rking fluid u ually hydrogen The wo king fl i d then accel erates thro gh a nozzle a s of rockets

The u e of wo king flu d of low mol cular we ght nabl thus ro ket t p odu e a high r sp c fi mp l than a chemic l r ck t in wh h tl e work g fl d s m xture of the products of c mbus- ll wev r th t mperature lim t of 4000–5000 F imp ed by exi t ng re t r and nozzle mater als pre ent the full p tent al ti s of the nucl r r ket from bei g r al z d at p ent *See* NUCLEAR AIRCRAFT PROPUL IO NUCLEAR ROCKET

The h gh int n ty ne tron d gamma rad ation fr m th r acto heat adjacent h rdwa e o that t mu t be ol d S m e equ pment and human er w can be h lded with relat ase by heavy shadow sh elds compl te enclo re is unn ces ary n nterplan tary pace f r the i no a r to scatter the rad at n Alter t vely act r and ns t ve p load ca b widely s parated w th con iderable a ng n w ght but w th th introdu t on f addi t nal des gn probl ms lso act r and pr pul s on flow ontr l are c mpl x and intricately related

Fu n ea t ons may s m d y llow the development of a c nd type f u l r cket Th y a d nde t able by p odu t and uld relea th rgy d r tl to the working flu d Howe er fu o techniq r t t be developed

The th d typ f n clea r cket now being n v t gated u e n gy fr m dio ctiv d cay lpha beta o g mm rad at o all three *Alph a d f ta parti l a adily nve ted to h at G mm parti les are h rmf l to electr ic q pm t d h man be gs and r qu re h eld g l ot pe f l i pen i t produc ts l fe is l mited a d a p op il ive y tem u ing top would r quire pe i l ol ng pr i n l e aus h at evol ed by th fuel t ll t m s S h n ng would be s table prima ily f l w thrust E n so with hyd g n as tl e w rk g fl id and uffi tly high temperat r s h y t m can be xpected to d l p a spe ifi mp l e of 600 00 sec

Becau f th potent aliti of thes clea p pul on m thods, they a e be ng studied *Th ir t hn cal dev l pment aw ts furth i t fic kn wl dg*

El ctri al p p l i The xp ll nt mat al n be g n high loc t b ele tr c l mean Th ee ba typ f electr l p opul n are re h t g n j ti a d m gnet pla m a el r t n Ar h ati g n e l tr l he ting f the w k g fl d 15–0% of th lectri l ene gy appe ng d ectly a k t energ in th o k g flu d By g th pr p llant ge er t e cool ant 50–60% f th lectric l e gy be co ted t k n t e rgy At p es nt elect od r n l m t l f

In i d m g t pla m p p l the rk g fl id l r d l ct i lly i t ad of th r mod m lly l on v on f th i rocket, ta t f tw d m l m t r l i izes the p pella t hi h i th n a el r ted in a l ctrostat fi ld in es f 10 000 olt Specific m pul es f over 60 000 e appear feasible Electrons are disch rged near the i n j t t neutral ze it The propellant is preferably a material of h gh atomic we ght *See* ION PROPULSION

In a magn t pla ma ro ket a fluid of ions and electron (the total fluid b ing electrically neutral and called a pla ma) is a *cele ated by reaction* w th a changing magnetic field or by interaction of an electr c cu rent and a teady mag et c f eld (see ELECTROMAGNETIC PROPUL ION) Th pla ma can l e restra ned magnetically s that as t heat the ngine w ll are prot ted With a fluid f low at mic weight such s hyd ogen a cel rated by a changing m gn tic field a specific impul e in ex s of 15 000 ec s pos ible It may be feasible to transfer o er 90% of the magnetic nergy into k net c e e gy by thi method *in its pr ent f rm* the el ctr cal equipme t is he vy nd complex S e MAGNETOGAS DYNAMICS

A teady th u t can be pr du ed by pa ng an ele t ic urrent thr gh th plasma orthogonally to the fl w and t a steady magneti field In this w y a pecific impulse of 1000–1500 c seems possible

The ele t ical power for prop l ion ould be p duced va usly (Fig 1) The r latively fixed c t cal mass of n clear fis on react s, and to a les er extent the hea v sh elds for i tope and r a t s do not i crea e proporti n tely with p wer output Th r f r the extr ct n of high el ctric p wer f om the e ng s may improve the o er all thru t weight rati

Waste h at fr m the ng nes must be r jected nd th eje t n temper tur d t m nes the th r m dynamic effic nc (see C RNOT CYCLE) Th we ght of adi to s f heat r je t on m t be i cl ded in the eng ne weight E e so th efficiency of therm dynam c tu bogene at rs today s much gre te than that of pre ent de elopment l d ect thermoelect ic en rgy conve te th t th more c n e ti al m thod appe r to be p f rabl for high power r qu r m nts

S l h ting The wo kin flu d f a rocket c n b h ated by olar rad ti n t temperatur of

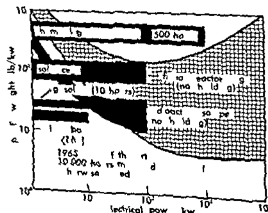


Fig 1 Sp f w ghts f l l ct l pow
U l f th A o/Sp c S)

1000–2000 F (*see* SOLAR FNGINF) At the Earth s distance from the Sun a reflector area of 8 ft²/kw is needed if 100% of the captured radiation is converted to power (*see* SOLAR CONSTANT) Considering all the losses probable in uch a heater from accuracy with which the reflector is pointed at the Sun to efficiency of a solar boiler the reflector area may need to be 80 ft²/kw At Mars distance from the Sun the reflector would need to be 200 ft /kw Just how such a reflector for a high power ystem would be transported into space remains to be determined

I hoton propulsion The radiation pressure of the photons from the Sun is about 10 lb/ft at the Earth s distance The total pres ure due to action and reaction on a perfectly reflecting surface w uld be twice this value Although force is limited by being directed only away from the Sun olar ail ing can provide low thrusts and attitude control turning a space hip completely around in a few hours Because no working fluid is carried in the vehicle this type of prc pul ion i ec nomical in weight

For the vehicle to carry its own light ource a photon rocket of adequate thrust would neces itate energies far beyond pre ent capabilitie Becau e the photon velocity is the speed of light relativistic effects mu t be considered Also the need for cooling of mirrors precludes a practical device u ing pre ent technology

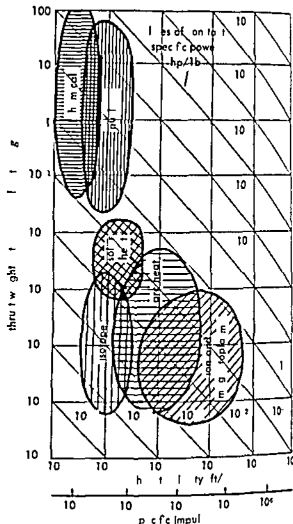
Performance evaluation Fach space flight requires particular engine performance Thus there is no best engine l ut there are engine better suited for some mis ions than for others The tal le pre ent data for the principal types f engine Figure 2 shows the relation of acceleration (which is al o the thru t weight ratio f the vehicle) to pecific impulse (or exhau t velocity) and to pecific power (which is here the ratio of kinetic energy in the jet per unit time t the over all weight of the vehicle including its source of energy)

Chemical and nuclear rockets provide high thru t for short duration The other engines perate for long durations at low thru t F r sh rt trip rapid acceleration is de iral le for long trip low ac

Ranges of specific impulse thrust to weight ratio and duration

Sy t m	Sp f i	Tl t to w gl t t o	Typ l l t
Cl m l	00–1 0	10 ²–10	Mi tes (l gl tl t) H (l w tl t)
F	00–1 100	10 10	S l m l y t m
Isot p l y	100– 00	10 10	D y
A l t g	100– 000	10 ⁻10	D y
M g to pl m	5 000– 000	10 10	W k
I	5 000–60 000	10 10	M tl
Sol h ti g	100–700	10 ⁻10	D y

\ p



F g 2 Regions of acceleratio s and spec fc po er for var o s rocket (J rnal of the Aero/Sp ce Sc enc s)

celeration may produce usable over all flight time For such service a interplanetary freight the h h specific impul e of the electrical units would allow a vehicle so powered to carry a heavier payl ad than if dri en by a chemical rocket

Trajectory requirements The even l a ic interplanetary maneuvers are pre ented in Fig 3 t gether with the engines suital le f r each The interplanetary flight really starts from a satellite orbit bey nd the greater part of the Fartl s atmo phere It is a umed that the energy neces ary to lift a ehicle off the ground and to put it into a atell te rbit i pr vided by eparated rocket l ter e hi le To minimize the energy nece ary to o er c me the relati ely trong gravitational field the thru t h ul l be applied during a l rief period Chemi al and nuclear rocket are theref re the nly suital le engines for this maneuver Int r planetary propulsion need supply only the energy to accelerate from orbital vel city and for the ther interj lanetary maneuvers

Interplanetary orl it transfer is the next maneu ver Ba ically it is the overcoming of tl e gra ita ti nal f ld of the Sun and the correcting f r d f ferences in tangential el citie of the launching

m uv	E c	c	I d p I	h p h	E pl o E		k	I
sc pe f m bt	O	)		O	O	O	)	O
pl ry tr f	O	O	O	O	O	O	O	O
h g f pl	O	O	O	O	O	O	O	O
t	O	O	O	O	O	O	O	O
ect ry echo	O	O	O	O	O	O	O	●
g pproa h	O	O	O	O	O	O	O	●
pt	O	O	O	O	O	O	O	●

O t bl O pt bl ● d bl

t g l d ect f d

Fg 3 S t bl ty of p opul yst m t dff t i t pl t ry m U l f th A /Sp S e)

a d the ta g t pl net Th d al zed minim m en gy att i ed whe fly g the t j ctory of a so-alled Hohma n ell p t t ge t at t phe- l to th bt f the o t r pl et a d t it p h l t the bit f the i e pl et nd h the Su t t p me f A p r t ppl at n f th t may b u ec ry f r tl m n u e n il a f te tr n fe rbt eq g great en gy f ll wed b u the e gy may b p- pl d t tl me tim a th ape man r S Ellipse

Th bt f e h pl net tilted t a d ffe nt b t m ll a gle t th pla f the ecl pt c De- pe d ng pon the po t f la n h n d th targ t pl et d pon the reg n f the fl ght tr ject ry wh h th ehi l h ges from the pl f the bt f pla t t the pl ne f th bt f th th n e rgy pp i ble gy may be q ed

A h l r t t n m y n ed tr l fo h p t a g t l b rv t d m m t r f ec i g la e gy O e way t h thi tr l s t l w thr t p o- p l n y tem r y l nt l f g t mpo t n e A multiple- zzle m opr p lla t t m a y f sol r d t p es fl t appea t b d ll t d f r th m n u

T aj t ry rrect c n l m d l wly The en gy r q ed f r h r t n d pe d p n th r h ul de gn f t r espec lly th err s igat dev es gu d a d ntr l a d pon th pl t a d th e u a y f th m p of the sol y t m

A th h l ppr a hes th ta g t pl t h g i loc ty m y be eeded t mat h th b tal loc ty f th pl t abo t th S The th t n es ry d pe d pon th t m g f th m

The last prop l on equirement i s milar to the fi t but applied in re e se The ehicle i de el r ated fr m its olar tra sfer o bit to a satellite orbit about the ta g t planet Thi maneu er requ res rel ati ely high a elerat n to o ercom a high gravi t t onal field although n t o h gh as i requ red for a land n m neu er b ca se the eh cle may make a p ral appr a h F r e gines of h gh thru t weigl t r tio (l rg r than 0 5) the appr ach p th to the ta g t pl n t is en itive t the t mi g f the thru t appl cat o It w ll may b that the in tial capture o b t qui e rre t on Th pe d with which the man ver is to b car ied out determines to some e tent the r qu red thru t

Mi s o n ds Interplan t ry mi sion c n be gr ped in th ee teg ries each equir ng a d f f nt m nt f nergy for interplanetary tran fe o b ts (1) mi n the immed ate i inity of E th d Moo (2) mi i n with n the nner o- l r sy tems out to th b t of Ma s and (3) mis- s o t th uter l r s tem bey nd Ma s

F r the fi t cate ry of mi on hemic l sys- tem e adeq te but a c lerati ns bel w 0 01 *g* r too m ll to be useful Po s bly uclear or i ome lim ted ca es olar h at ng eng es ould als be u d f r m f the t an f r m ne er

Fo m o s w th the i ner lar y t m ac el rat o s of 0 0001 g a e at sfact ry f r the d s- t nes a d fl ht time n l ed The s m p op l n sy t m m ti d ab e a al o suitable for the e fl ght except that ery effic nt electrical g nes m y b added

F r mi n t the o ter lar sy tem a cel ra t s gr ate th n 0 00001 g w ld p od ce at s f t y t j to e wh ppl ed r the peri ds of sever l m ths r year n c sar f r uch flight B c u of th r h gh p cifi impul e the elect i al p op l n systems a e uniquely qu l fied f th e mis n

In e l it c n b a d th t i t plan tary h l s w ll c t f e l sta es or st ps d that e h tag w ll hav its own p opuls n sy tem D pe d ng up n th ex t m eu th g nes in th r us t ges w ll be d ffe nt a d it i f a ibl t e th m type of tag f m than ne n t rpl n t ry ma e

Be au f the eed f botl h h a d l w thr t d i g a terpl n tary fl ght a p pul n ystem th t c uld be th ttled w ld be u ful in me e p id d th ch g n th st we e n t a c mp ed by s r o l s in pe f rmance The t p decay r ck t n l a ock t and electric l dev n be th ttled If pecifi impul does n t cha ge u fa bly th ottl g e n s v h le e ght nd z

Pre nt-d y p wer suppl w th p c fi w ght f 20-30 lb/hp ng pr p lla t that d l v r spe cifi imp l es f 300-400 ll w m der tely fa t o d t ip t Mar If ocket eng o ld be t ted t w ld p de the thru t f ever l of th lem t rv ma Th pr p llant n t pended n e l r ma r wo ld be a ailabl

1000–2000 F (*see* SOLAR ENGINE) At the Earth s distance from the Sun a reflector area of 8 ft /kw is needed if 100% of the captured radiation is con verted to power (*see* SOLAR CONSTANT) Consider ing all the losses probable in such a heater from accuracy with which the reflector is pointed at the Sun to efficiency of a solar boiler the reflector area may need to be 80 ft²/kw At Mars distance from the Sun the reflector would need to be 200 ft /kw Just how such a reflector for a high power system would be transported into space remains to be de termined

Photon propulsion The radiation pressure of the photons from the Sun is about 10 ⁷ lb/ft at the Earth s distance The total pressure due to action and reaction on a perfectly reflecting surface would be twice this value Although force is limited by being directed only away from the Sun solar sail ing can provide low thrusts and attitude con trol turning a spaceship completely ar und in a few hours Because no working fluid is carried in the vehicle this type of propulsion is economical in weight

For the vehicle to carry its own light ource a photon rocket of adequate thrust would necessitate energies far beyond present capabilities Because the photon velocity is the speed of light relativi tic effects must be considered Also the need for cool ing of mirrors precludes a practical device using pre ent technology

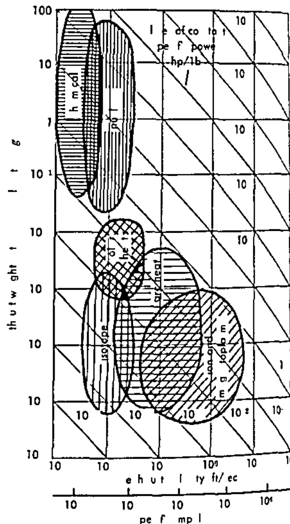
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Chem cal and nuclear rockets provide high thrust for short durations The other engines operate for long durations at low thrust For h rt trip rapid acceleration is desirable for long trips slow ac

Ra ge of sp cif c imp lse thrust to weight ratio and durat o

Sy t m	Sp c f c m p l	Tl t t w gl t t	Typ l l t n
Cl m l	00–4 0	10 ²–10	M t (l gh th t) H (l w th t)
F s	500–1 100	10 ²–10	S m l m l y t m
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A h t g	400– 000	10 ⁻–10	D y
M g to- pl m	5 000– 000	10 10	W k
I n	5 000–60 000	10 10	M th
Sol h t g	400–700	10 ²–10	D y

\ p



Fg 2 Regions of accele ations and spec fc po n for various rockets (*J ur al f the Ae o/Space S e ces*)

celeration may produce usable over all flight time For such service as interplanetary freight the high specific impulse of the electrical units would al w a vehicle so powered to carry a heavier payload than if driven by a chemical rocket

Trajectory requirements The seven ba ic inter planetary maneuvers are presented in Fig 3 to gether with the engines suitable for each The inter planetary flight really starts from a atellite orbit beyond the greater part of the Earth s atmo phe It is assumed that the energy neces ary to lift a vehicle off the ground and to put it into a atellite orbit is provided by separated rocket boo ter e hicle To minimize the energy nece sary to o er come the relatively strong gravitational field the thru t should be applied during a brief period Chemical and nuclear rockets are therefore the only suitable engines for this maneu er Inter planetary propulsion need supply only the energy to accelerate from orbital velocity and for the other interplanetary maneuvers

Interplanetary orbit transfer is the next maneu ver Ba ically it is the o ercoming of the gra ita tional field of the Sun and the correcting for dif ferences in tangential velocities of the launching

m	h mi l	r	iso p d y	h ll o	m g t pl m		sol h f o	sol l
escape from orbit	O	O	O	O	O	O	O	O
inte pl ne ry tr f		O	O	O	O	O	O	O
ch ng f pl ne	O	O	O	O	O	O	O	O
one ta io	O	O	O	O	O	O	O	O
trajectory correctio	O	O	O	O	O	O	O	●
targ t pproach	O	O	O	O	O	O	O	●
cap re	O	O	O	O	O	O	O	●

O tabl O acc p bl ● nd robl

force g neral d rection f rad tio

Fig 3 S i b l ty f io p p l io ystem to d'ff re t t pl t ry m vers. U t f the A /Sp S /e)

a d the t rg t pla et Th de l ed m im m n e g attai ed when fly g th t ajecr y f so lled H hm n ell p e t t g t at it the l t th b t f th o te pl net nd at it pe h l n t th bit f the n pl n t and h th Sun at it p im focu A sep r te ppl t n f thru t m y be n ecessary f th man u ev n f fa te tr f bit equ r g g t r gy f ll wed beca the gy m y be ap pl ed t th me t m th e p ma S Ellipse.

Th b t f e h pla t t lted t a d ff re t but m ll a gle t the pl n of th ecl ptr De pe ding upon th po t of l un h ng and the t g t pla t and pon th regi n f th fl ght t ject ry whi h th h le ha ges fr m th pl n of th b t f n t la et t the pla e f th b t f th th ergy r pp ec ble rgy m y b q ed

V h l r t t m y need t l f u h pe t n at al b rnat rad m m n ti n r f ec g l r e gy On wa t a h ev thi co t ol r l w thr t p o pul t m c u f o t l r f gr at mport A mult ple n zzl m n p p ll t s tem n tr f sol d au n p es u e r fl tors appe rs t be d all ted f th m n u

T ject ry co rect n be mad l wly The rgy req d f h c rre t d pe d up n ther h c l r d fa t pe all th rro n g t devi e g d n d t ol a d p a th pl t a d th u y f the map f th l syst m

A th h l pp hes th ta get pl n t a b g in loc ty may be need d t m t h th b tal l city f th pl n t ab ut th Su The thru t rv d pe d p tl tum n f th m n r

Th la t prop l i n requ r m nt i m l r t the fi t but appl ed in rev r e The vel i le f dec l r ated fr m t solar tr n fer tl t t n s t ll t rl t about the t rg t plan t Th m e t r t r r l att ely h gh a c lerati n t mes nme a l gh g avi tat o l field alth ugh n t so high a t re red f r a landing ma e v er becau the h el may mak a p r l app ach f r ngin of high thr t weight rat (larg r than 0.5) the appr a h path t tl targ t pl n t t t tl t ming f tl th t ppl cati n It w ll may be tl at th in t l c pture rl t requires correct n Th peed wit wl h th man u e t t be carr ed t d t rmin t sum e tent th req ed thr t t.

M s n ds Interplan t t m a be grouped n th ee c teg s each req i ing a d f fere t am t f ene gy f r int plan tary tran fer b t (1) mi in tl immediat v init f E th d M ( ) mi n w thin th inn r o lar tem ut t th rb t f Mar and (3) m s to th o t r sol r y tem be nd Mar

F tl e fir t cat g ry f m i n f mi l ys tem ar a f q te h t a el rat n bel w 0.01 g ar too mall t be u ef l P lly ucl ar or in som l mited a es lar l at g engines could l al be sed f f th t n f r man u r

F r mi with n th r sola t m c l rat f 0.0001 g a at f t ry f th d s ta es nd fl ght t m t l ed Th m pr pul n y tem m t ed also at also t l l f r these fl gl t s pt th t e y eff i nt electri l ng nes may be added

F mi n t the ter solar sy t m a l ra ti n gre t r th n 0.00001 g w uld p od sat s fa t y tr j t r es wh n ppl ed the p d f ev ral m th r y t necess ary f r uch fl ght Because of th r h gh pecifi impul the electri al pr pul y tem a uni y ly q al fed f th e mi

In ge e l t can be said that interplan t r e hi l w ll n t t of e tal t ges tep and that h t g w ll ha e tt wn p d y t m D p d ng upon th t man u er th ng es in th tage will l d ff nt d t t f a t le t u th ame type f t g f r mor than on in terpl net y ma u e

B au e f th eed f r both h gh a d l w th u t d g a nte plan t ry fl ght a pr p l i n y t m th t uld be th ttl d w uld l u eful in some es p o ded th h ng n thru t we e t mp n d b u l p f rman The t pe dec y rock t nuclea rock t and lect cal d c n be th ttled If pecific impul does t ha g u f rably thr ttl ng c n s v ehicl w ight a d

P e nt day p w uppl with p cifi weight f 20-30 lb/hp u n p op lla ts th t del r pe cifi mp l e f 300-400 ec all w a m derately f st und t p to M s If o k t e gi c uld be r tarted it w uld pr v d the th st fo se eral f th s ve el m t ry m neu r The p pell nt not xp ded n a l e man u r ould be a il ble

for later portions of the trip Even so having at least two stages—one for high and one for low thrust—seems favorable for interplanetary and or bit transfer maneuvers

Environment During any of these missions the engine with the vehicle is exposed to unusual en vironmental conditions Prolonged exposure to high vacuum precludes use of materials that evap orate For example some soldered joints contain materials that will slowly evaporate in space

Over most of the interplanetary trajectory gravi tational acceleration will be very small Positive acting switches and other components are thus necessary gravity cannot provide a return force Similarly a liquid and its vapor will be difficult to separate In space electromagnetic radiation and corpuscular impacts may alter the properties of the materials used in the engine and in the vehicle

The over all vehicle should maintain thermal equilibrium Ambient temperature can be con

	d t p e to	f t a bl th t	v d bl v to	t k off l ry p w	g owth p b l ty	l t mpl ty	st t ap b l ty	d mp g t of	P l ab l ty t day
lq d p pella t h m l	○	○	○	○	○	○	○	○	○
ol d p p ll t h m l	○	●	○	○	○	○	●	○	○
f s	○	○	●	○	○	●	●	○	●
t p	●	○	○	○	○	○	○	○	○
c h t	●	○	○	○	○	●	○	○	●
m g topl ma	●	●	○	○	○	●	○	○	●
	●	●	○	○	○	●	○	○	●
s l he t	○	○	○	○	○	○	○	●	○
l l	●	○	○	●	○	○	○	○	○

○ w ll k ow f bl ○ t o l m ted
● l g ly pl d d ff lt

Fig 4 Compa on of technical featu es of propul on syst ms (*Jo rnal of th Ae o/Spa e Sc e ces*)

hem l	3	
f	3	
i t p de y	3	
a c h ting	6–8	
m g to pl sm	6–8	
o	6–8	
ol h t g	3	

0 5 10 15 20
n mbe of b y t m

Fig 5 Relat e comple ity of va o s prop lsio sys tems (*J rnal of th Aero/Sp c Sc e ces*)

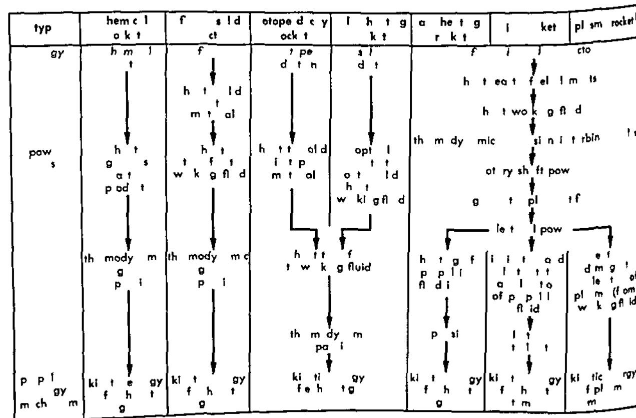


Fig 6 Energy con ers o s in a ious rock t (*Jo r l of the A o/Sp ce Sc e*)

e lled by rfa e mater al that re e e rad at on rom th Su nd ad te energy int pac Energy rom nten ely hot port ons of the ngi e req i re ffecti e d tr I t n A large th rmody am c I est k (ad ator) nec ary f r me eng nes n es the h a d fr m mete ic impact

Sm ll I st m v ng part cles ar a hazard to all ps e h cle Pen trat on by a part le m y c lo s ol g s pr r pr pell nt or coolant or m v a t e s e nce trati ns eriou f r such highly l aded k n Solid pr pellants may l e p e m tu ely gnited m chi ry may be e dered i perat e Pr t ct e me u e i It de dupl cat ng sy tem m im zing th ize f eh cle a d the ex t sed urf ce and pr d ng hea y wall The hea y wall may al b eeded fo struct r l stre gth as in h m cal r ket o for ad t on p tection a i nuclea o k t

Until a f w i t rplan t ry p obe return w th d ta the exact nvi onme t of pac rema ns the bje t of onjecture

Engine development Engi des gn and oper ti nal requ ements ry fr m m s n t m s n M y mi r q e th appl at on of thru t at d ff e t t m s ally by taging or occa ionally by e t rtabl nes Ign t n n a v c um and e p l f I quids f m t nk at ro g ty a e d ffi lt Th e a d the g n devel pm ntal f at es re umm rized in F g 4

F n g ti n l b erv t ns a d f r ma eu er ing the p p l n y tem may be eq i ed to p o d c tely ntr II ble t rque a d l w thr t n di et th r than th ginal fl ght d r t n These d th r ope at o l equ r m nt w ll n fi n e the lect of the e gi f pe fic m

F mpari n I ba p p l on y tem lau el abil ty an be defined b ed on th n mbe f m jo ub y tem nd f the mple ity f gy O th b i tl el t cal yst ms t d to be th lea t r l able t sh wn Fig 5 Th m wh t rbitrary energy on o s d d f tl ev l at a h wn n Fig 6 The l qu d m n pr pella t v t m appears to be p rt larly tt t not only f it sim pl t b t l f its ab l ty t top and re t rt a d f r t d g fl bil t O the l a of the e ject ed mi so th hem al r k t ca be pected to b th m t rel bl e gi e f a l ng t m t m

Lo g d mpli ted p fl ghts w ll q e l b l t th t x eed th e f much qu pm t w sed Ea th T a ason ble u s e t l fl ght m y nec t t uch xte gr u d t ti g nde m lated d t n t m k et l fl ght te t g m d r ble d h ap D pl t (r d d t) y t m w ll b u ed f l l I i Al e er l l bl eng es th p es w ll b l t r d Th f h g ne h el b l t f 0 99 (1 f l 100 t) l t r 17 e g 5 f a d a p w ll (l nly o 9930 ope at o Only tl ch m

l q d propell t	O	O	O	O	O	O
sol d p pell t	O	O	O	O	O	O
monopr pella t	O	O	O	O	●	●
f ion	O	◐	◐	◐	●	●
f io	◐	◐	●	●	●	●
radioa t isotope dec y	◐	◐	◐	●	●	●
hea g	◐	◐	◐	●	●	●
mag pla ma	O	◐	●	●	●	●
ion	O	◐	◐	●	●	●
sol h t p	O	◐	◐	◐	●	●
sol l	◐	●	●	●	●	●

O ompl d l bl

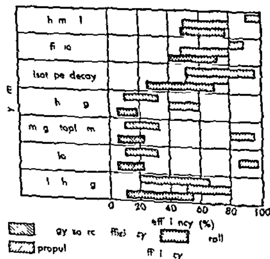
d w y

● accompl hed or l bl

Fig 7 De elopm t t t of va io ock t gi s (U f f th A /Spa Scie)

cal rocket has been dev l ped s ff cie tly so that the r l bil ty is high eno gh f r u h clu ters g t b eff ti For the next few ye r it will b tl e nly a ilable e g ne fo int rpl netary flight Work other gi e type h s been i iti ted (*Fig 7*)

Th e gines th t d rve th gre test eff rt are th l wing the great t pr m se both in ff ci nt of the r e ergy so ce and in effici t c n r



Fg 8 R l y ff c f p w fo d ffe t p p l y t m U l f the Ae / Sp S)

sion of energy to high thrust as summarized in Fig 8 The chemical and nuclear engines are the only ones with a high acceleration capability If an efficient lightweight electric generator could be found the electric systems with their versatility would be highly attractive and accelerations higher than 0 00001 g could be attained See SATELLITE ARTIFICIAL SPACE STATION SPACE TECHNOLOGY *see also* SPACE FLIGHT SPACE VEHICLE SPACE CRAFT STRUCTURE [G P S]

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Suppose as is often the case that it is desired to describe graphically the results of an experiment in which some quantity Q is measured for example the electrical resistance of a wire for each of a set of N values of a second variable v representing perhaps the temperature of the wire Let the numbers Q $i = 1$ 2 N be the measurements made of Q and the numbers v be those of the variable v These numbers representing the raw data from the experiment are usually given in the form of a table with each Q listed opposite the corresponding v The problem of interpolation is to use the above discrete data to predict the value of Q corresponding to any value of v lying between the above v If the value of v is permitted to lie outside these v the somewhat more risky process *of extrapolation* is used See EXTRAPOLATION

Graphical interpolation The above experimental data may be expressed in graphical forms by plotting a point on a sheet of paper for each pair of values $(v_i Q_i)$ of the variables One establishes suitable scales by letting one inch represent a given number of units of v and of Q If v is considered to be the independent variable one usually lets the horizontal displacement of the ith point represent v and its vertical displacement represent Q

If for simplicity it is assumed that the experimental errors in the data can be neglected then the problem of interpolation becomes that of drawing a curve through the N data points P_i having the coordinates $(x_i y_i)$ *that* are proportional to the numbers v_i and Q_i re pectively so as to give an accurate prediction of the value Q for all intermediate values of v Since it is at once clear that the N mea urements made would be consistent with any curve passing through the point ome additional a sumptions are necessary in order to justify drawing any particular curve through the points Usually one assumes that the v are close enough together that a smooth curve with a simple a variation as possible should be drawn through the points

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$$y = P(x) \tag{1}$$

lected number of points of the set having coordinates $(x\ y)$ The interpolating function $P(x)$ should be of such a f rm that it is made to pass readily thr ugh the selected point and is easily calculated for any intermediate value of x Since many chemes are known f r determining quickly the unique th degree polyn mial that sati fies Eq (1) at any $n + 1$ of the tal ulated alue and since the alue of such a p lyn mial may be c mputed u ing only n multiplications and n addition p ly nomial are the mo t c mm n f rm of interpolating functi n

If the sul ript on x and y are rea igned so that the po nt through which Eq (1) pa e are n w $(x\ y)$ $(x_1 y)$ $x_n)$ the polyno-

In ded i Eq (1) may be wr tten down by in
:t and o e has

$$y = \sum_{k=} \frac{L_k(x)}{L(x)} y_k \qquad (2)$$

re

$$L_k( ) = \frac{(x-x)(x-x_1) \quad (-x)}{(x-x_k)} \qquad (3)$$

i i Lagranges nterpolati n f rmul f r u ally pa ed rd nat s Snc $L(x)$ van hes for x in the t x x x except x sub t ing $x = x$ n the ight hand ide of Eq (1) gi es e t ly o e o e o t rm Th term h s the iu y s r q i ed

F r $n = 1$ Eqs ( ) nd (3) g e i e t th u ti n

$$y = \frac{x-x}{x-x_1} y + \frac{x-x}{x-x_1} y_1 \qquad (4)$$

iose pl t a tra ght l e on ecting th po nt $(x\ y)$ nd $(x\ y)$ Su h n inte pol t n i re- rred t l n ar nt rpol ti and ed in all me t ry d c on of int pol t n h wever other q i l nt form of thi eq at on g en be- w Eq (12) is m re ft n u ed in these a es

S ppo e th t bl w obta ned f m th eq n $y = f(x)$ n wh h $f(x)$ i some math mat c l t h i g cont nu s d ti es of all rder p t and n lu l ng th (+ 1)th It i then po i l t bt n an e rat exp es i f r int rmed te lu f $f(x)$ by addi g t the r ght h d side f Eq (2) so- all d m i d t rm

$$\frac{(-x)(-x) \quad (x- \ )}{(+1)^{!}} f^{(\ )}(\xi) \qquad (5)$$

h e $f^{(n)}(\xi)$ th (+ 1)th d ri ti e f $f(x)$ at m p t $= \xi$ ly g b tw n the mall e t a d l gest l th l es x_0, x x_n S th al e f ^{e} i n t known the remai d r term u d m r ly t set an uppe l m t on th tru c t on o t od ed by s g Lag g s i te pol tion form)

If th di te a eq lly p ced th t s $=$ + h wh r h i the nterv l of t bul t n Lagr ge s nterp lat n f rmul mpl fies d ably and may b wr tt

$$y = \sum_{k=-p} A( )y = A ( )y +$$

$$+ A( )y + \quad + A \ ( )y \qquad (6)$$

wh th degr f nt polati g p lyn m al th t w l th gh th $+1$ p nt $(x_{-p}, y \ )$ $(x_{n-p}, y \ )$ H p s th l rgest nteg r l s th n or q al t $/2$ d the A ( ) A ( ) e polynom l th ar bl

$$= \frac{x - \ _0}{h} \qquad (7)$$

The latte p lyn m als h ve b en t b l ted a fu t f u

Inverse interpolation If the valu f y i known and the alue of the correspon ling independ nt variable x i de red ne ha th pr l l m of in er e interpolati n S nce the polyn mial $A(u)$ in Eq (6) are kn wn fu cti n f u and th alues of y and y_k are also known th nly nkn wn in thi equati n i u Thu the pr l lem redu es t that of find ng a re l roct u f an nth-degree polyn mial n the ra ge $0 < u < 1$ (F d se i n f nu meri al methods f r sol ing f r su h a root and f r m re inform ti n on i terpol ti n s NUMER ICAL ANALY IS) Ha ng f u d u n may f nd x f m Eq (7)

One may also perf rm an inv rse int rpolati n by tre t ng x as a f ti n f y S n e howev r the interval between tl y are n t eq al it i nec es ary t empl y the g neral interpolati n f r mula of Eq ( ) with the x and y int rchanged

Round-off errors In th tal ulated values, ro ind off errors , res lting fr m th nee l to xp es the entr es y of th tal l a fin t decimal w ll cau e an additi nal rr r in the int rpolated val e of y that mu t be added t th trunc ti n err r dis cu ed before The effect f these rr r on th appl ati f Lagrang i t rpolati n f rm il i seen by Eq (6) t be a total er y in y g n l y

$$\epsilon_T = \sum A_k(u)\epsilon_k \qquad (8)$$

Letti g be malle t po ti e n mber ti fying the co d ti $e > |\epsilon_k|$ f r all k ne has fr m Eq (8) that

$$|\epsilon_T| \le \sum |A( )||\epsilon_k| \le \sum_k |A_k( )| \qquad (9)$$

S ce the s m of the $A_k( )$ i eq l t l the f t r

$$\sum_k |A_k( )|$$

n Eq (9) s u ually n t much la g r th n 2 o 3 a d th s th i t rpol ted alue f y has abo it the am round off err a the i di dual entries

Use of finite differences F some purposes it i mo e c nv ent to u e an interpolat g f rmula based n t mu h n the ent es y of a ent al d ffe enc tabl as pon their diff rences

x_{-2}	y_{-2}				
		δy			
x_{-1}	y		$\delta^2 y$		
		δy_{-}		$\delta^3 y_{-3/2}$	
x	y		$\delta^2 y_0$		$\delta^4 y$
		$\delta y_{1/2}$		$\delta^3 y$	
x	y_1		$\delta^2 y_1$		$\delta^4 y_1$
		δy		$\delta^3 y$	
x_2	y		$\delta^2 y$		
		$\delta y_{5/2}$			
x_3	y_3				

E ch d ff e δy is obtained by subt acti g th q antity immedi t ly bo e and to the left of

sion of energy to high thrust as summarized in Fig 8 The chemical and nuclear engines are the only ones with a high acceleration capability If an efficient lightweight electric generator could be found the electric systems with their versatility would be highly attractive and accelerations higher than 0 00001 g could be attained *See* SATELLITE ARTIFICIAL SPACE STATION SPACE TECHNOLOGY *see also* SPACE FLIGHT SPACE VEHICLE SPACE CRAFT STRUCTURE [G P S]

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$$y = P(x) \quad (1)$$

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If the subscripts on x and y are reassigned so that the points through which Eq (1) passes are now (x_0 y_0) ($x_1 y_1$) (x_n y_n) the polyno-

i e les of $f(\ )$ tabulated at some interval $x = h$ they are admi ably d pted t numerical omputat ons F thi r a on m t numerical o- ition of d ffe ntial equat n in ol e approx iating the equ tion by a u table d fference equa on

For ord nary diffe ential eq at on the transfor iation to a d ff rence quation can be made by re- l c ng ea h deri ati e in the equati n by the ap- opr ate diffe ence expre on c rd ng to the ormul

$$f^{(2\ )}(\ ) \to \frac{1}{h^{2}}\delta^{2}f(\ )$$

$$^{2+}\ (x) \to \frac{1}{2h^{2+1}}\left[\delta^{2+1}f\left(x+\frac{h}{2}\right)+\delta^{2+1}f\left(x-\frac{h}{2}\right)\right] \quad (15)$$

here $f\ \ (x)$ de ignat the th deri ati e f (x) The d ff r ce equation resulting can then me ti ned befo e be u ed to expre s the r la o h p betw en the lues of $f(x)$ at th discrete nts $x = x + sh\ s = 0\ 1\ 2, \ \ n$

Partial difference equations Suppo e one ioo es to pe ify a funct on of tw ariables (xy) by giving ts lue t om reg l r array f oints in the y plane ha ng coordinat s $(x_m\ y\ )$ h n, n pl ce f l n ar p rtial d fferent al equa fo $f(xy)$ e ha l n ar partial d ffer n qu t n

$$\sum A\ f(\ _{+}\ y_{+}) = g(\ \ y) \quad (16)$$

h e $g(xy)$ a kn wn fu ti a d i nd j ny f th t f inte f wh h the d ffer nc qu ha s gn fi an e A diff re ce equation n h ch s me of the $f(\ \ y_j\ )$ cu to a power the th n the F t s t rmed n l n r d ff rence q u

If empl ys qua e latt c make-up of the oints

$$x_m = \ _0 + mh$$
$$y = y_0 + nh \quad (17)$$

i n Lapl d ff nti l quatio s app ox i ted by th d ffe n q t on

$$f_{+\ }+f\ \ +f\ \ +f\ \ -4f = 0 \quad (18)$$

h r f r s mpl ty lets

$$f\ = f(x_m\ y\ ) \quad (19)$$

e GRAPHIC I T IODS LATTICE (MATHE IATICS) [K.S K.]

B bl g phy K. S K nz, *N m ri al Analy is* 9 7 *T bl f Lag a gia I t p lat n C effi nt* 1944

Interstellar matter

h mate i l betw e th ta s Int t lla matt i k t p e n known in many way N ly ny l g xp s ph tograph f a a n the l lky Way t ke w th a fa t t l pe w ll how bright pat hes of nebul u material The ligl t fr m the patches xhibit emi ion l ne spectra charac teri tic of a gas at l w den ity Other cl uds are bright becau e they reflect the l ght of a n arl y star or sta s and hence mu t be made f mall s l d parti les. The e cl ud and the illuminating star have s milar pectra Frequently stars h e a redder color than i predicted by their pectral characteri tics the result of int rvening material not unlike mall dust particles which reddens any light pa ing thr ugh. Di tant stars often exhibit absorption l nes in their spectra which are pro- duced by interstellar gas Fin lly the light of many stars is polarized a d the correlation between the d gree of polarization and the d tance of the star suggests that a material of crystalline form exi t in interstellar space

Nearly all interstellar material in our galaxy is located in the spiral arms Rad o ob rvati ns have detected hydrogen ga in the nucl us of the galaxy but no obscuring matter has been ob erved In other galaxies the ch racteri tic emissi n spectrum f interst llar gas is frequently seen particularly in the spiral galaxies Spiral galaxi s seen edge-on always show a c nspicuous band of absorbi g ma terial silhouetted again t the bright nucleu and spiral arms *S e* GALAXY EXTERNAL GALAXY THE.

Bright gaseous nebulae Only in the neighbor hood of a tar hot enough and bright en ugh t e *cite* the gas to luminescence can ther be a bright g eou nebula (s NEBULA GASEOUS) The tar t elf may be the ource f the ga s i the ca in pla et ry nebul a d the shell around e n vae a d p rno ae (s CRAB NEBULA) Th Ori n nebul i the best kn wn d ff ga eou nel ul (s O ION NEBULA) The electr n den ities det r m ned for g eous neb l e ar l th order of 10 10⁴ lectr n /cm and the k n tic temp ratu es are a und 10 000 K. Th r compo iti n a e s m lar t tellar atm phere e n t ng of abo t 90% hydr gen atoms and 9% h l um t m l y number of t m

Alth ugh o d ary *ga eo s* neb lae requ e th p ese e of a defin te cl ud of inter t llar ga ga oc ur n mo t part of r gal xy with a h gh gh d ns ty t be detect ble by spect l cam e a t th ic n t of y hot bright tar Beca the ga is l g ly at m *hyd* en and m tly i zed uch f i t object a e called H II regi ns H re the d nsity may be s l w a l atom/cm and the r d u of the reg o of ion zed hydr g n m y exte d t ie 10 parsecs (326 light years) H I (ne t l hydrogen) regio s ha e been d te ted by bs rv ng th hyd og n em s on line of 21-cm wa el gth with rad o tele pes Here aga n the d n ty is about 1 atom/cm a de ty wh ch se ms t be typ c l f th pace in th r g o of o r gal axy occup ed b the Sun

Reflection nebulae Frequentl b ight d ffu nebul e ar ob rv d p e ing dark l p c tra. Su h nebulae *contain* mall sol d part cle or g a n wh ch reflect the l ght f ne rby star o

it from the quantity immediately below and to the left thus

$$\delta^k y_s = \delta^{k-1} y_{s+1/2} - \delta^{k-1} y_{s-1/2} \tag{10}$$

where k and $2s$ are required to be integers For example

$$\delta y_{1/2} = y_1 - y_0 \quad \text{and} \quad \delta^2 y_0 = \delta y_{1/2} - \delta y_{-1/2}$$

An interesting property of a difference table is that if y the dependent variable tabulated is a polynomial of the nth degree in x its kth difference column will represent a polynomial of degree $n - k$ In particular its nth differences will all be equal and all higher differences will be zero For example consider a table of cubes and the difference table formed from it by the rule given above

x	$y = x^3$			
0	0			
		1		
1	1		6	
		7		6
2	8		12		0
		19		6
3	27		18		0
		37		6
4	64		24		0
		61		6
5	125		30	
		91		
6	216			

Most functions $f(x)$ when tabulated at a small enough interval $\Delta x = h$ behave approximately as polynomials and therefore give rise to a difference table in which some order of difference is nearly constant Consider for example the difference table of log x in which the third differences fluctuate between 7 and 9 times 10

x	$y = \log_{10} x$	δy	$\delta^2 y$	$\delta^3 y$
1 00	0 0000 000			
		43 214		
1 01	0 0043 214		−426	
		42 788		8
1 02	0 0086 002		−418	
		42 370		9
1 03	0 0128 372		−409	
		41 961		8
1 04	0 0170 333		−401	
		41 560		7
1 05	0 0211 893		−394	
		41 166		
1 06	0 0253 059			

Experimental data if taken at small enough interval of the independent variable would be expected to exhibit much the same behavior as a mathematical function except for the presence of experimental error The presence of the latter will cause the differences to have a more or less random fluctuation The size of the fluctuation may in fact be used to indicate the number of significant figures in the data

The constancy of the third differences for log x indicates that for the accuracy and the interval used a third degree polynomial may be employed as an interpolating function Since such a polynomial is determined by the choice of four coefficients one would expect the interpolation formula to involve four numbers derivable from the difference table Thus the forward interpolation formula of Gauss

$$y = y_0 + u\,\delta y_{1/2} + \frac{1}{2}u(u-1)\,\delta^2 y_0 + \frac{1}{3!}u(u^2-1)\,\delta^3 y_{1/2} + \frac{1}{4!}u(u^2-1)(u-2)\,\delta^4 y_0 + \frac{1}{5!}u(u^2-1)(u^2-4)\,\delta^5 y_{1/2} + \cdots \tag{11}$$

If terminated after the fourth term it represents a third degree polynomial in $u = (x - x_0)/h$ and hence in x It involves the four constants y_0, $\delta y_{1/2}$, $\delta^2 y_0$ and $\delta^3 y_{1/2}$ Since any one of the entries in the y column may be chosen as y_0 the differences required are picked from a central difference table for example in relationship to this entry The interpolating polynomial obtained passes through the four points (x_{-1}, y_{-1}) (x_0, y_0) (x_1, y_1) and (x_2, y_2) In general the interpolating polynomial will pass through only those points whose y coordinate is needed to form the differences used in the formula

If one terminates the series in Eq (11) after the second term one obtains the formula

$$y = y_0 + u\,\delta y_{1/2} = y_0 + u(y_1 - y_0) \quad (1$$

This is the linear interpolation formula most often used when making a simple interpolation in a table

There are a great variety of interpolation formulas Gregory Newton s Stirling s and Bessel s that differ mainly in the choice of differences used to specify the interpolating polynomial

Difference equations Repeated application of Eq (10) may be used to express any difference in terms of the tabulated values thus for example

$$\delta y_{1/2} = y_1 - y_0$$
$$\delta^2 y_0 = y_1 - 2y_0 + y_{-1}$$

Expressed in a more general form these become

$$\delta f(x) = f\left(x + \frac{h}{2}\right) - f\left(x - \frac{h}{2}\right)$$
$$\delta^2 f(x) = f(x + h) - 2f(x) + f(x - h)$$

If one sets the second difference equal to zero one obtains a so called difference equation for $f($ In general a difference equation is any equation relating the values of $f(x)$ at discrete values o

Difference equations play much the same role in analytical work as differential equations because they may be interpreted in terms of o

group of stars Studies of these particles in reflection nebulae suggest that they have high reflectivities and are nonmetallic Probably they are ice crystals or compounds made up of the lighter elements The nebulae always appear slightly bluer in color than the illuminating stars indicating that the particle diameters are in the vicinity of 10 cm

Light scattered by small particles is usually polarized and photographs of reflection nebulae taken through polarizing materials show that the polarization can be as high as 35% Also the effects of radiation pressure can frequently be seen particularly when there are highly luminous stars in the vicinity of the nebula (Fig 1)

Frequently bright diffuse nebulae such as the Orion nebula are composed of both gas and particles as is evidenced by their spectra which contain both emission and absorption features

Dark nebulae When silhouetted against a rich star field or a bright nebula a cloud of solid particles becomes apparent by absorbing or scattering away radiation directed towards the observer Many dark nebulae are to be seen in the Milky Way regions of the sky where the light from distant stars is dimmed reddened and often polarized The distance to a dark nebula can be found approximately by determining the distance to the most distant unreddened (or unpolarized) stars, which must of course lie between the Earth and the nebula Also if it is assumed that statistically all stars are of the same intrinsic brightness a distance can be estimated Here counts of stars per unit of angular area in the sky within a small range of apparent magnitude or brightness are made and compared with neighboring areas of the sky The dimming effect of the nebula will cause a sudden decrease in the density of stars fainter than a critical apparent brightness which correspond statistically to a certain distance

One of the best known and nearest dark nebulae is the Coal Sack which is about 120 parsecs (400 light years) away The Gulf of Mexico area of the North American nebula is about ten times farther away *See* Coal Sack

While particle clouds which obscure stars must be reasonably large to be detected dark nebulosities seen against bright nebulae can be observed in all sizes Perhaps the best known example of this type of obscuring cloud is the Horsehead nebula which is located between us and an emission nebula (*see* Nebula) Numerous small dense clouds have been photographed with large telescopes Such objects called globules are often as small as 1000 astronomical units (10^{1} km) in diameter (Fig 2)

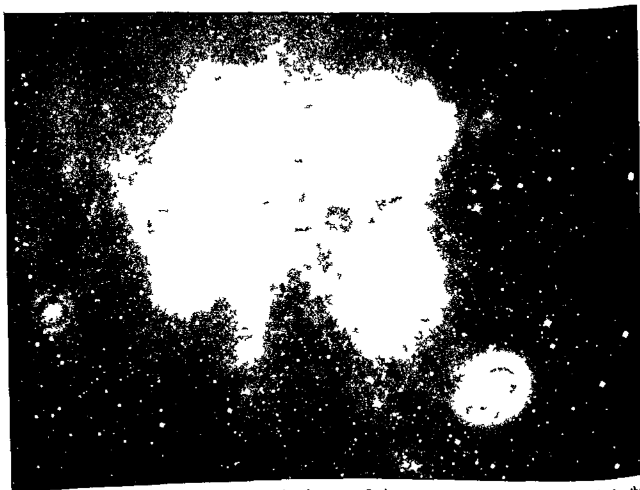


Fig 1 Reflection nebula associated with the Pleiades star cluster The cloud with a brushlike pattern is composed of small solid particles about 1μ in diameter Radiation pressure is probably responsible for the streaked appearance of the cloud Photographed with the Curtis-Schmidt University of Michigan



Fig 2 Part of th R tte b l NGC 2237 h ws m tu f i t rst llo g d g s. The d t p ss from th b ght r rs l the low left rn f th ph t g ph i bl w g th ld g way d t th sam t m b k g ff gl b l Ph t g ph d d l ght w th th 48-n S hm dt t le p f th M u t P l m Ob rv t ry

D k b l e m y ab rb a ywhe e f om only f w p e t f the l ght t ue f r m ny dif fu l d e p oj ted ag t th M lky Way t e t lly all th l ht mu t c r f r the d kest gl b les th ugh wh h ften no light n be e The l ght t a mitted by the le den e n bul e le t l bs bed m ki g it p ble t t m n l t reg d g th natu l th pa t l n th bulae Th ab o pt n r es o hly th tp c l f th w el ngth f th l ght d f om t d es of the b pt n pr p t f mall p rt cl L G H ny y a d J L. C t fo d il t h b ha gg t th t e th c y t l a ging bo t l μ n di m te m t ll p rt l b t 10 m n d m ter a p odu i g th ab pt Be f th xpe ted la g p po t o f l ht l ment x r g t p e t m e bl i t l eve that d k n b l omp d f ec y tal

Interstellar gas Oth g s th n that wh ch r n i tbl n bul ha b n d t t d thr gh t b pti l h h an b b erved t th pect f d ta t t r l te tella l ne n b d t gu hed f m the stell r tm ph r c l by th i t m r wn d be a th y d n t h b t th am D ppl h ft th ta The t ng t l e e produ d g ally by met l h a l i m (b h the ut al and ngly n z d t g) sd um nd i n a f w m l ul f atu ha bee b ert d u h b n nd hyd g o b d it ge The b rpt n l n f th l ght nd t ly m b da t at mo n tal ly hydr g n are n t l served l ecau all xe t t on occur fr m tl e gro ind tates and no lin fr m such tra ti n appear in acce ll le regi n of the spectri m

The r d ati n d n ity in i t r tell r pa t ex tremely l w l we er the en rgy di tril iti n cor r p nd appr imately to that f a l la k l ly at 10 000 K a ha l een d t rmined l y the am unt of i n zati n Thi t mperature and tl e relati l ne strengtl s l ad t an erage d n ity of int r stellar g s t our regi n f pace f abo it 1 at m/cm³ Becau e th ga i larg ly hydrog n tl l valıe cor e ponds to about 10 g/ m

Beca se many int r t ll r lines ha e ev ral c mp n nt when b erved with h gh l p r i n it kn wn that i t r tellar g t nd to a cum late i nd v d ial cl ud a h m ing with it own p a ate eloc ty t p ce Ofte the velocities c r re pond t th f the spiral arm in which tl e cl ud are loc ted Thi mak it pos il l t u e th clo d to outl ne th l ape of a port n of the gal xy

The 21-cm hydr g n l n f freq iently ee in ab rpt wh n l d f neutral hyd og n ap p ar in fr nt f t ng t f r d emi i n

Interstellar particles In m ny w y the d tr buti n f th i t r t llar part cles res mil l tl t of the g s Alth gl tl re a decided tende y f r th se p rticles t a umulat in cl ud they evertheles permeate all f inter tellar pa e within the piral arm f r gal xy All d tant ta appe r redd ned l y th mat rial and ar dimmed corr pond ngly The int r t ll r bso p t as f dark n b l ries appr x mat ly a the re pr al f the wa el ngth of the light Tl degree f redd n ng f tarl ght an be est mated f l acc tely by c mparing the l erved c l r w th that p ed ted f m tl e spectr m f tl tar H wever t is not so a y to determ n the t t l b pti at a g en wavel gth Ther f e mu l eff t h s been xpe ded i trying t fi d the r ti f tot l t sel cti e bsorpti The best e timate gge t that n th a erag in o r region f the gala y app xim t ly 50⁰⁰ f the l ght of a t r at a di tan f 1000 p secs (3260 light years) i ab bed If the gr prod g tl is ab rpt n are ce c y tals l μ n d amet the density f the i te st ll r p rt le mu t be i the icin ty f 30 p rti l /km 10 g m a alu wh h ab ut ne hu dredth that f i t r tella g s

Be au e f tl e h gh entrati n f i te tell r mat ial towa d th plane of the gal xy the a er ag l f ab o ption p it d stance rap dly de rease m re d t nt ta s e b rved in di r t o t r ght a gles t the gala t c pl ne Con e sely it e t em ly d fficult to detect d tion w th w el ngth l th n l μ c ming f om large d ta e n d rect ns) t the galacti plane Th zon f vo da ce whi h r pond ughly t the a ea oc up ed by th Milky Way i th t re g i th sky wh h e nt ally n e t agalac t objec t n b e b c u f the t rven g t t lla m t r l

Intestine

The tubular porti n of the d ge ti e tract between th tomach nd the anu In man it c n i ts f the small a d large ntestines The former s further di id d i to thr e maj r part the duodenum the jejunum a d the l um The duodenum 10–12 in long begins at the pylo ic phincter of the t m ch and curve arou d the head of the p n c ea the r ght de f the upper abdomen It recen the duct of the biliary sy t m and the pan r as Th j jun m and il um are abo t 19 ft lo g nd form a mu h o led tube th t emptie t ght angl nto the large bow l thr ugh the il o- cal l

The l rg bowel or c lon con ts of fi e parts th end ng t an ie e descend ng and igmoid eg s nd the termi l rectum which empt es th n l c al

All p rt of the i te t ne are upported by mes- e es l ry ng ext nt, wh ch conta n an ex y tem of arterie e ns, lymphatics, and rves to the r ou reg n

The mi r op c structure f th ntesti e om an in e glandular m c s conn cti s bmu a mu cula at and n o t r r a of onn t e ti ue wh ch s co e ed n m t a by pe itone m

The f n t ry w th th egion b t nclude imarily d ge t n d ab rpt n of food e c e- n of wa t s d e t o of d gesti e ju c s See IGESTIV SYSTE t [E.G.ST]

ntestine disorders of

h d of the i t t in l d o genit l de- ts a d l r mech n al d gen rat n l mm t ry a d eopl t dis rd r

Th mo t c mm g tal d (t Me kel i v t l m a pou h r t a i wh h pe i t as the em ant f the fetal umb l c l du t Othe malf r m t o (s i de el pm t a e n mmon Va c l lesi i l d m s ter c th mbosi a blocki g f th art al supply r ve ou d ain g f the i t t n by th mbu mbol It s f eq ntly c t d w th t aum he rt fa lu e r rte l

Comm n m h n al d d a e hernia the p t n f a loop f b w l th o gh a d f t o w k ss f th bd m l wall nd perito al d h r ult ng f om c t r ld p iton ti wh h oft l d t nte t al b t uct n Intu us ptio n fr qu t d d seen m t oft inf nt i h h o part f th t st t le- c pes t th t gment Th blood upply may b r d d nd bst u t n may s lt S m la res lt m f ll w lvul the twi t ng of a l op of t t n t wn me e t i talk th sup- port g f ld l p t um.

Th th e d g n at e l w th th h ghest d n pr mu scid s and Wh ppl s d b t ll s r l ti ely omm n The fi t m k d by f tty fo l m ll g bulky tool (t t rrh) d a m c pli ity of oth l n c l symptoms The second is an inborn deficit of pan creat c secretion that cau es steat rrhea other symptoms includ sali ary a d sweat gland abnor mal ty and a thma *Whipple s di ea e* is a rare disea e of middle age in which large fatty deposits accumulate in the intestinal walls and in the mesen teri s

Inflammations include non pecific and specific disea s (see ILEITIS PEPTIC ULCER) Tuberculo- si typhoid fever amebia i ch lera and bacillary dy entery pecific infecti d sea es produced by in a i n of microorgani m may produ e intestinal lesi ns Variou chemicals and poison may also produc i flammations f the small intestine (en te iti l r of the large bowel (coliti) Ulc rati e col tis is a di a e of unkn wn cause wh ch pro- duce ulc rati ns of the intestine particularly the col n See AMEBIASIS BACILLARY DYSENTERY CHOLERA VIBRIO TUBERCULOSIS TYPHOID FEVER

Append c tis i the m t freque t pro ocati n of urgery f the abd men It probably ari es from a combinatio of cau es, including infection and ob- struction f the l men and lso from para itic in festatio s The prompt surg cal removal redu es the n mber and everity of c mpl catio ene n t r d in unt eated ases *Append citi s* ma be an ac te fulminating d ease r may persi t as a chr n c recurrent inflammati n w th mu h scarring a d final bliteration f the l men

Maligna t tum rs f the mall inte tine are not common but the large inte ti e has a h gh inci de ce of arcin m s whi h account for 15% of all ance de ths each year in the Un ted States Oth r mal gn nc es are lymphoma Hodgki s d ase mal gna t m la ma a coma and leuk m c in filt atio s *Se* ONCOLOGY

Ben gn tum rs a e represe ted by polyp lipo- ma my m s a d fibroma d u ually occur in th c lon the *mall* int t ne rarely being invol d

D order of the p riton um d th r abd minal rga s may di ectly r nd rectly i volve th intes- ti e *Other* ra e cond t on xi t that m y affect th ntestine any) stemic disord r may also pro- du intest nal changes r dy fun tion [E C ST]

Inulin

A eserv p lysa charid in some plants e pec ally those i the f m ly Compos t , wher it i found in the root a d tube s of the dahl a Jerusalem arti ch ke a d dand l on Inul is nly sl ghtly solu ul l in ld w te but r ad ly d ssol es i hot w t r It d es not gi e a c l r eact on w th iodi h s l ttl r duc ng p wer d s l rotat ry $[\alpha]^{20}_{D}$ −40 (n wat r) Its m lecular weight i ppr xi mately 5000 whi h c rr spond to hai length f ab ut 30 f ctof ra e res due It i hyd o- l zed with a id r the enzyme ula from *As pe gillus nig* to D-f ct s The nulin m lecule is made up p inc p lly of f uct furano e u ts li ked β glyc s d cally fr m th hyd oxyl gr p on car bon 2 t th p imary al oh l gro p n carb n 1 *S e* FRUCTOSE OPTICAL ACTIVITY POLYSACCHA RIDE

Starlight is not only absorbed by the particles in space but also scattered giving the sky a faint luminous appearance Such glow is one component of the light of the night sky other contributors are air glow or permanent aurora and the integrated effect of large numbers of extremely distant and faint stars *See* AIR GLOW AURORA

Polarization of starlight A W Hiltner and J S Hall found that most distant stars shine with measurably polarized light the total percentage polarization is never large amounting at the most to a little over 7% Because of a strong correlation between the amount of this polarization and the degree of interstellar reddening there is no doubt that the interstellar particles produce the polarization The planes of polarization of stars near the Milky Way have a strong tendency to be parallel to the galactic plane suggesting that the interstellar particles are crystalline in structure and are oriented by a general galactic magnetic field

Origin of interstellar material Much interstellar gas has probably remained in the same state since its origin However a sizeable fraction of this gas must come from stars through the ejection of material by prominence and flare activity and from the shells of novae and supernovae The interstellar particles grow through gradual condensation of the atoms and molecules To grow a crystal 1μ in diameter takes about 10^{8} years neglecting the infrequent collisions of the particles There seems to be little variation in the sizes of interstellar particles from one part of the galaxy to another indicating the existence of an equilibrium state

Formation of stars V A Ambartsumian first pointed out that superluminous stars of high temperature which cannot be very old because of the tremendous rate at which mass is converted into energy are always found in clouds of gas and interstellar particles Such associations are clear proof that stars must form from this material Once a reasonably large condensation of interstellar gas and grains forms it is not difficult to show how a star can evolve However the process of how such condensations form is not clear Perhaps eddies in a weak magnetic field produce them By blowing away the more tenuous material radiation pressure would separate these condensations producing the small dense globules which have estimated masses comparable to those of stars *See* STELLAR EVOLUTION [W.LI.]

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Interstellar space

The space between the stars and other celestial bodies For convenience of reference the space in the immediate vicinity of Earth is termed near space (*see* SPACE) The intervening region from Earth to the Moon is cislunar space farther from Earth is interplanetary space Interstellar space is strictly the region beyond the planets This article deals with both interplanetary and interstellar space

Nowhere in the universe is space absolutely empty it is occupied by extremely tenuous matter generally gas and solid particles from dust to meteors of 0.1–1 cm diameter and large meteorite debris

In the solar system at least 99% of the solid mass filling space occurs in the form of tiny particles of dust having diameters of 0.001–0.1 mm The sunlight reflected from this dust cloud is visible as zodiacal light showing a strong concentration near the plane of Earth's orbit (*see* ZODIACAL LIGHT) The dust is dark its reflecting power being about the same as that of soot Its total density is about 1 $g/500\,000\ km^{3}$ There appears to be a comparable amount of interplanetary gas mostly completely ionized hydrogen at least partly consisting of a continuous stream from the solar corona

The meteoric and meteoritic component of matter in interplanetary space represents a much smaller mass about 1 $g/10^{9}\ km^{3}$ It is more conspicuous because individual meteors and meteorite falls are observable from Earth

Comets with nuclei diameters of 0.1–10 km and asteroids (0.1–500 km) form the next step During millions of years meteor craters on Earth and on the Moon have been produced by collisions with these bodies Unlike meteorites they can be observed individually in space from a distance with the aid of telescopes

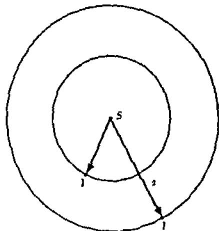
Interstellar space near the plane of the Milky Way is filled with gas mainly hydrogen of an average density of 1 $g/10^{9}\ km^{3}$ Everywhere it is accompanied by dust grains having diameters of 10^{-5}–10^{-4} cm The total mass of dust is about 0.8% of the gas and the gas accounts for about 2% of the mass of the Galaxy (*see* GALAXY THE) The dust obstructs light but unlike interplanetary dust it is white and scatters light without much absorption Gas and dust appear to be gathered into cosmic clouds 10–50 light years in diameter and with densities 10–50 times the average density in interstellar space Interstellar gas is transparent its temperature depends greatly on the radiation of nearby stars and varies from 10 000 °C near hot stars (H II regions) to −170 °C (H I regions) The temperature of the dust is everywhere very low −250 to −170 °C

In the space between galaxies the density of matter is perhaps a millionth the density in interstellar space

Interplanetary and interstellar space also contain primary cosmic ray particles which are atomic nuclei travelling with nearly the velocity of light and contributing a weight of about $5\ g/10^{4}\ km^{3}$

Electromagnetic radiation including x rays ultraviolet visible and infrared light and radio waves travels everywhere throughout space (*see* RADIO ASTRONOMY) Visible light is emitted by stars infrared radiation by the dust grains and radio waves chiefly by ionized gas

[E.J.OP.]



F p t S em n g e qy f I t dy I
h e q I w t t s that $I/I_2 = 2/$

ly f part l es a acuum u h a ra t e t m p ded the e ar n lect m g t field a d no m tu l t t a t Th t rm s so ed for tat field la u h a th l w f avitat n d Co l mb l w n lect t t cs

[W R S M]

Invertebrata

d i n of th an m l k gdom wh ch ha no ta m tat I l ded u der th term In erte t a e ll th e anim l whi h l ck p n l c l mn b kb e t a t t Vrtebrat W th he x pt n f the phyl m Ch d t all othe phyla f the s bk gdom M taz a a w ll a th f th bk gd m P t zoa Mesozo and P ra zoa a in t b tes *S* MESOZO METAZOA PARAZOA VERTEBRAT

[C B C]

Invertebrate embryology

Th tudy f the de l pme t r mo ph ge es and gr wth f the n rteb ates The ame ge e l p n pl of d l pme t pply t the rt b t th y d t th rteb t A tu lly mu h f the ba k wledg f mbry l gy h b en th es h f t d th rt b tes A mm n ph m o th i rteb t s th le s of a f e d d p de t f m the l rva befo e de lopm t mpleted The larv ry c n d r bly d ch te ti of th d ff ent m l gr ps

Th l f the ast maj ty of erteb t m l b g with th u n f n egg nd a p m t zo n Wh l these p duct ells kn wn llect ly g m t ould ha dly b m un l k e h th n mo t pects th y ha tw im p rt t f at es n mm n th p es n f a gl set f hr m m d th h ra t i t c f be g t gg ed ll Th p rm t oo tr gg r es a form ha ge i th gg rf ce wh ch e bl t t pe t at nd stimulate th gg Th l tte i tr gg ed t r p nd to thi st m l t n by b g n g the er es f mpl at d p oces es wh h d w the spe m toz t th gg br g togeth r the tw ... make up the d ul le t charact ri tic f the pe e c nd event ally e able thi fertilized egg cell to tra l te the heredit ry mes age int a faithful repl ca f the ancestral org n sy tem

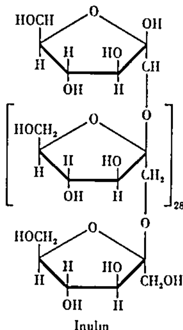
Aside from these t c mm n pr perties h w eve egg a d permat z a are highly d imilar While the n cl i of both und rg the proce of me s s whi h pr pa es them for eventual uni n by reducing the r hara teri t c chrom some number t one half the c u es f preparati n f ll wed by their cyt pla m le d in exactly oppo ite di ec t n

Spermatogenesis Number mp etnes and mobil t are important f r spermat T ward th end the proces of sp rm t g nesi c n t of a t ge f cell proliferat f llowed by a period of pr g e i e con e trat n and treamlin ng Th es e t l heredity det rm n ng mat rial f the chr m some s packed tightly int a tiny nucleu The cyt pl m f rms the locom t r apparatu u u ally a i gle l ng flagellum with a c ntr le at it b e nd a *mitoch ndri n ne rly a w ll* an org n lle (ac osom) for pe trat ng th egg c et ng Excess cyt pl m i fin lly di c rded and the matu sperm t zoon (Fig l) ready t take p rt in fertil zati n i a elf ntained t ipped-down un t arry ng th h reditary message in code nd pr vided with en ugh en rgy sour e t prop l it n a u t ined bur t of s tivity on its one-w y trip t j n an gg f it species M llions upon m ll n of uch cell are produced in the t ti whe e they rema n quiesc nt until th y are pawned *Se* SPERM CELL SPERMATOGENESIS

Oogenesis The gg i designed f r a very dif fe e t r l It mu t c nt in n ugh sub tan t pr ide stru tu al m te i l for the f rm t n f a et f simple org n f loc m t on and d gest n so th t th you g an mal an ec re food t arry on its further growth It mu t l cont in en gh en rgy yield ng mat r al t pe f rm th w rk of d di g the ingle gg cell i t body cell fr m wh ch su h o gans a be f rmed and to ynth ize the complex hem cal s b tan e needed t p o ide e h f the e new cells with a new nucleus *S* OOGENESIS OVUM

The egg th ref r is spe ial zed for large s z and p ot t n of its c nt nts with les c n rn f r numbers a d n n at all fo mot l ty In dd ti n t cyt pla m possesses int ns c capacitie f d f fer ti t o a d b ild g act ordanc with the spec ficat s c ntai d in it chrom mes s th t spider egg always pr duces a pider and ne e a fly The fa t that the phy l ba e of thes apac t e h e so far eluded most f th effort d ted t wa d the d te tion in n way ca ts d ubt on the ex t n e

Th r s rve build g and energy yi ld g ma te al a t ed the gg cyt plasm as m nute ph r s r pl telet f yolk a t bl lip pr te n h t Eg s a e l ge cell e n w thout thi in rt mater al At the e d of th r gr wth pe od



Inulin

Hydrolysis of inulin with inulase or baker s yeast invertase produces about 1 5% D gluco e It is not certain whether this glucose is an integral part of the inulin molecule or whether it is a constituent of an associated substance which is hydrolyzed at approximately the same rate as inulin [W Z H]

Inventory management

Companies often invest some working capital in materials used in carrying on the business The quantity and location of these materials control the annual total of the expenses and losses for carrying inventory ordering material and running out of stock collectively called inventory expense Inventory management is the work of minimizing annual inventory expenses which usually maxi mizes the return on the inventory investment

One phase of inventory management is to mini mize the quantity of material needed to conduct business This is done by standardization to reduce the number of different items that must be kept in stock by choice of plant locations by coordinating the number of products and models in the line and by extending the use of interchangeable parts and materials

Another step is to minimize the period that each item is kept in stock by scheduling and by choice of delivery lot quantity based on lengths of production cycles and forecasts of demand

Effective inventory management requires records of expenses costs and lo ses that come from carry ing inventory arise from ordering stock and re sult from running out of stock From such rec rds one estimates the effects of changing deli ery lot quantities lengths of reserve cycles and quantities of reserve stock Re erve cycle is tl e interval be tween the scheduled or expected dates of deli ery and u e Re erve stock is material that i on hand becau e a reserve cycle i allowed in scheduling the delivery of material Delivery rati is the p r centage of deli eries made on or before th day the material is required

Changes are planned by finding what the ex penses were for one set of delivery lot quantities and lengths of re erve cycle and estimating what the expen es will be for other condition Care must be taken to see that the data u ed in the cal culations represent expen es that actually will change For example space costs are a part of the cost of carrying inventory but a change in the amount of material kept in stock may not change the space costs

The delivery lot quantities and quantities of re serve stock can be calculated by examining the effects of changes in the e quantities on co ts and profits The delivery lot quantities usually are eco nomical when the related costs per year for carry ing inventory equal the ordering co ts per year plus the average costs of stockouts per deli ery The amount of reserve stock usually is economical when the cost per year of saving one stockout per 100 deliveries equals the value that will be paid for this benefit The practicality of the figures obtained from these computations should be re viewed by someone familiar with purcha ing and manufacturing problems The feasibility of plan ning deliveries analytically (*see* LINEAR PROGRAM MING) depends on the accuracy of the available data including plant needs and vendor perform ance

Inventory management also includes in talling and operating a material control system which en sures that material is usually where it is required when it is required Material control includes de veloping a signal that material should be ordered to meet known or expected requirements ordering material notifying expediters of the need to ex pedite delivery and performing related ta ks These tasks include setting up and posting perpetual in ventory records compiling records of quantities used where u ed prices sources kind and quanti ties of material used to make the item a ociated items and similar information Material-control personnel also gather store proces and di tribute inventory management data Effective performance of inventory management aids a company in im pr ving its competitive position *See* INDUSTRIAL CONTROL [L F S]

Inverse square law

Any law in which a physical quantity varies with di tance from a source inversely as the square of that distance When energy is l eing radiated by a p int source uch a law holds provided the space l etween s ur e and recei er is filled with a n n di ipative h m geneous is tropic unl ounded me dium (*s e* POINT SOURCE) All unl unded wa e be c me spherical at distances r which are large com pared with ource dimen ion so that the angular int n ity distril ution on th expanding wa e sur face who e area is pr portional t r i fixed Hence the in er e q are law

Similar rea oning how that the sam law ap plie to mechanical shear wave in ela tic med a and to c mpre i nal sound wave It holds stati ti

fert lized gg s l fted away from the surface after a sp rmat zoon h s entered and tr ngth ned by the add t o f mate i l f om the egg

Preliminaries to fertilization Sperm cell mt st omplet all the nucl ar and cytoplasm c hange nd be f lly mature bef re th y c n t ke part i fert l zati n On the other hand while thi s true f the cytoplasm f egg cell in m t peci s the nu l a p epar ti n for f rt l zati n s in mpl te he sp tm t n t ke pl ce Moreo er the deg ee of nc mpl t ne va i widely and apparently at andom

The mar n a el d *Nerei* sheds its eggs with th g m nal e cle ntact (F g 1b) Th en tr ce of spermat zoo st mulate the egg t b g th ed ct on di i and th sperm p onucle s w its within the gg c t pla m while th egg n cle s c rr es o t it p epar t on f ni n

Se h n eggs a e at the oth e treme in th s r pect Their reduct n d s on are ompleted i the ovary (Fig 1c) and the u o f egg a d *p rm p* ucl f ll ws immed at ly upon sperm e try I many oth r pe ies me o s b g n h rtly befo th eggs are pawn d a d stops at one stage anoth r f the proc ss unt l the ent anc of a sp rmat z n s is it goi g aga n (Fig 1d)

Rep od ct o am ng the invertebrates t kes place n a va iety of way wh ch differ w d ly fr m phyl m to phyl m F r e ample follow g *pul* t in *D o ph la* th p rmatozo are st red i a spec al part f the female rep oduct e tra t and r l a ed a f w t time as e h ovum pas es down the d ct t b l d Th p rmatozoa f squ ds re packaged n m ll b ndl s (*p rm tophores*) Th se e pl ced by the m le us ng ne of it a m wh ch is m d fi d for th pu p se in permatoph re recepta le the b dy f the female Th eggs ar fert l ed a they le e the v d ct and ar la d i gly n fing shaped gg mas es fixed to u d rw t bj ct

M t f the ech node m and many mollu ks c d n a nelids d el t ates shed their ggs n t mend n mber into the s a wat r whe e f rt l zat tak pl The you g larvae m t u ually fe d f r them l es In these ame gro p howev som spec es l lt r th y ng n se w te t ng ch mb a d po ket wh h e t a t lly with the body of the p re t a i m l Th s af the w th rthr pod su h as c ab wh h a ry th la ae ma es fi ed to th bd m of th f m l d m b al e n wh ch th y g d el p l t me with the mantle h mb B t wh th r the f rt l zed egg a thus p tected by th pa nt a mal l d i j lly m es l ath y ca f lly struct d b ood lls (b s b nt ng wa ps) i ply th wn nto th w t r ch egg n d pend nt un t cap bl f d l p g nt an dult w th t ny f rthe t h t n f m the pa ents

Fertilizat on B u f rt lizat n n m y teb ates w th th pr d ct t a t f th f m l It j wn ng ha t k n pl e n esp t t m l wh h a t well u d to d or experimentally r prodt cible it i hat lly s prising that the actu l proces hs been ol rved with the m cr sc pe in only a r latv ly few pe cies The e are howe er a number of i vertel rat am ng the form wl ich hed their gam t int th sea in whi h it i po bl t add p rmat zoa t egg nder th mier cope and h r the proce of perm e try ery clearly In th m t fa or l l ca es the course f event within th egg a il e tw pr nu lei un te and the *z g te proceeds* t und rg s cce i d i i n and diffe enti ti n can be f l lowed Read micro c p cal l rvati n req ires sm ll transparent egg wh ch are normally ferti li ed o t ide the body f the f male are a ailal le in l rge number a d remain fertilizable in the labo atory The egg of some s a urchin best fol fill these c ndit n and l a e pr ided much f tl e ava lable inf rmati n r lating t the f rtilizat n proce

The ea ur hin egg offers the f rther ad antage of ha i g c mpl ted it *redu tion d ri i ns* with the o ary s that it i in a relati ely tal le tate *when it is spaw ed It also re p nds to perm entry in certain easily rec gnizable ways which fac litate* tudy of the f rtil zati n proce As a resi lt it ha come to b g n r lly th ght of as a model for all fert l zat lthough it i actually a rather special ca

Th u fertil zed ea urchin egg (Fig 1e) i a *sph rical* cell abo t 90 μ in diameter s irr unded by n n isible layer of jelly abo it 30 μ thick It small pr n cl us l e eccentrically *in* the cytopla m wh h i c owded with mall part les About half *of these are* y lk sph re the rest a e mitocho dri p gme t granules a d va ious other minute bodies wh e funct n is not yet well under tood Di ectly under th a rf ce membrane i a compact layer of sp ial gr nule 1 μ in diameter called cort cal g nules (Fig 2a) El ctron m cr copy sh ws thes gra ules to be compo ed of at lea t two k nd of *m teri* l a d th y remain firmly in place und r centrifugal *forces* which mo other part cles t d ff rent part f *the cell*

The surfa e of thi cell *is* co red by a ry deli c te it lline memb an which li dir tly o er the l y r of rtic l gra ules When the fertilizi g sperm t zoo m k c tact with th s surf ce an impul e is tra mitted a und the egg from the p int f onta t The fi st detectable result of th s mpul is a hange *in* the cortical gr nules wh ch g i app at the p i t f sperm attachme t and sw ps around th gg reach ng th opp site s de in about 20 c nd This ch ge on ists f a swell g f n of the c mp n nts of the granules cau ing th m to bur t a d s parat th vitelline m mbran fr m th st of the cytopla m A c l lo dal sub t nc r lea ed into the spa e b l w the r i ed membra e take p wate and swells so that by about a m nute afte p rm tt chme t the mem bran i free fr m th cyt pla m c s f ce all a und th gg (Fig 3a b)

While this oc urs the p rmat zoon i b ng drawn i to th gg By tl e tim the sp rm head

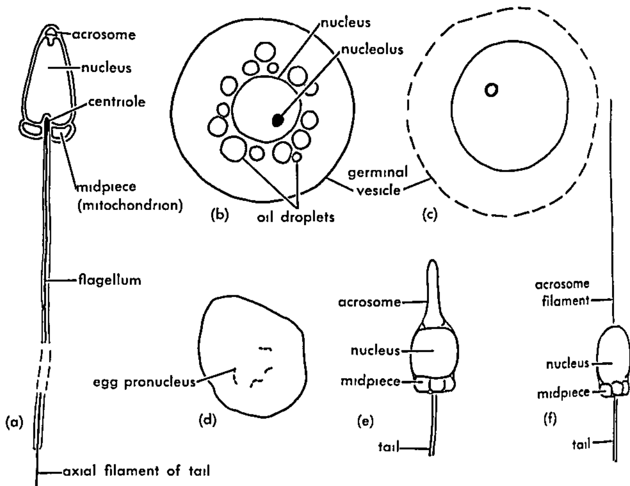


Fig 1 Spermatozoa and fertilizable eggs (a) Sea urchin spermatozoon (b) *Nereis* egg (marine annelid) with intact germinal vesicle containing a nucleolus Spheres surrounding germinal vesicle are oil droplets (c) *Mytilus* egg (marine mussel) germinal vesicle broken down but polar bodies not formed (d) Mature egg of *Arbacia* (sea urchin) containing egg pronucleus (e) *Mytilus* spermatozoa (mussel) acrosome intact (f) *Mytilus* spermatozoa acrosome reaction

when they have accumulated the full amount of yolk they are huge in comparison with the body cells of the parent animal No invertebrate eggs however achieve the spectacular dimensions of bird eggs The largest are found among the arthropods (crayfish eggs are 2 5 mm in diameter) while some marine animals have very small eggs (oyster eggs are about 65 μ)

During the growth period while the egg cell is actively synthesizing yolk and increasing the amount of cytoplasm it has a very large nucleus the germinal vesicle (Fig 1*b*) When it reaches full size however and this synthetic activity subsides the nuclear membrane breaks down releasing its contents into the cytoplasm (Fig 1*d*) The two successive nuclear divisions of meiosis follow but the cytoplasm instead of dividing equally pushes out one of the daughter nuclei each time as a polar body These two minute bodies have no further function in development The chromosome material left in the egg forms the egg pronucleus (Fig 1c) which is ready to unite with the sperm pronucleus The zygote nucleus formed by their uni n is comparable in size to those of the body cells

Polarity of the egg Many types of eggs how structural departures from radial symmetry which indicate that the unfertilized egg is organized around a bipolar axis one end of which is called the animal pole and the other the vegetal pole The polar bodies are given off from the animal pole and the egg pronucleus remains in this region When an egg contains conspicuous amounts of yolk it is usually concentrated in the vegetal half of the egg

Egg membranes Since the eggs of invertebrates are often shed directly into the water of oceans and streams or laid to de elop in places where they are exposed to the drying action of air and sunlight they are always surrounded by a protective co er ing In some forms the eggs are laid in batches which may be enclo ed in a leathery sac or em bedded in a mass of jelly In other ca e each egg has its own separate membranous ca e a layer of jelly or a more complex system of protecti e struc tures

If the young animal is to l egin its de el pm nt under expo ed c nditi ns as do many in ect the egg is provided witl a tough co ering (ch ri n) which is imp enetral le e en to its spermat z a In such ca es th re is a minute h le (micr pyle) in the chori n near the animal p l through whi h the fertilizing spermat zo n can ent r Am ng echinoderms the delicat vit lline meml rane of the un

Ext nd ng in all d rect n und thi po nt the av soon re ch th c ll rface (F g 3d) P b- ably a th re ult f th pu l e e t d lere by tl e r c ntinu ng lon ati n th nter of the a ter con ta n n the p rm p nucleu mo es l wly t wa d the cente f the egg At the ame t me the egg pr ucleu beg n t m e (Fig 3) t wa d the nte of the p rm a t r that t ward the p rm p nucle s wh h s n w bl a a lear phe e st ll m hat maller than the egg pro u l Ten min t s at m t afte pe m entr e th two pr nucle l e in c ta t (Fig 3f) urr nded by tl r y f the p rm ter These co tinue to el n g t c rry ng th apposed pron cl t th cent r f tl g a d te d t the m mbrane on all ides The un n of th tw pr n cle (yng my) ma k th c mplet f th f rti l zat n p ces The tu i form the zygote nu l u with th full c m plement of hr m somes and th d rmant e g ell h s b e arous d to t n m tion the ere of h n es wh h will p du a n w ea r hin A n umb r f the ents wh h ha ju t been d sc bed r p ul t e u ch W th d ffer t tim l ed les nd allowa ce fo th indi idu l h a te t s of h p e h wever these b pr c es f perm t y ter f rmat n and ing my mak p th compl x phenome on f th ti l zati ti n it r in all an m l S

ERTI IZATI N

S h a d er pti e pres t t n gg t m ny uest on bout what s tuall g ng on n term f ll fa a t n d t n On h q es- t f x mpl n th natu f the n ct b t ee p rm t zoon a d e g u fac It s m that n m rtebr te the r some t h t r tip f the p rm ell n lergoe a e pl e ct n at th egg urf ce wh h t ns- form t t a rv l nd r fil me t (F) f) I at f t som a es an en mel k ub t n i l o l ed f m th me whi h h d l ng ff t th g m mb Th e i d th t th p netr t n f th g rf by th s fil m t e t th egg m h n lly Wh th r t s l o ful d aw g tl p rm t zoon n d the gg yt pla m h s y t t b p o ed

Th at of the pec ficity wh ch en r s that gg w ll b ent r d o ly by p m t a f th wn p ies h l l th bject f gr t l f es ar h d ha t ll t r e ed tho ughly t fa tory pla t on Th mech n sm by wh h gg th t h rec i d p rm to- oon ejects ll l t rr al i an th p blem th t res t sol i n b t p rhap m d ffic lt t d c e than th nsw t a f the q e ti ns r th e on i g th cytopla m diffe en es betw nfert l z d d fert l z d g

Cleavage Th f rtil ed g o zyg te, t abo t at e t d id th huge m s of the gg i t many m ll lls n rd r to r t e th al rat b t n th m t of le r and yto- pl m bstan Th ne gy f these p ated m t es mes f m th yolk h h l f rn hes t l t p rt of the m t l q ed fo s thes s of n w cl tructu es Du i g th s l g per od whi h comm nly occur dur ng th fir t 12 h urs fter fertilizati n the l la t m res a the clea ge t g c ll ar called di ide more r les vn hro u ly Generally clea age f ll w one of es ral pattern wh ch i cl aracteri t l r larg gr up f animal and i lten c rr lated with the am u t and m de f di tr l t n of th y lk

Whatever cle vag p ttern i f ll wed the plane of the fir t cleavage pa tl r ugl the an m l p le When the egetal r g n nta n a larg pr por t n f y lk le age i retarded in tl i area and the bla t meres tend to be l rg r than in th ani mal pole r g n

Sm ll gg wh h r nta n l ttle y lk di i le com pletely and u ually ery regularl f ming a ma of ell that h w pir l (m ll k Fig 4a b) bilateral (a d ns, F g 4c) r rad al symm try (ech oderm F g 4d) S me coel nt rates h w e cl ave i to what app ar to be rand m m es f c ll (F g 4)

Th ery l rge egg of squid ntain a gr at deal of yolk co centrated at tl v g tal pol Th l av age fur ow do n t e i ll the way thr gh thi p rt but restri t th r ct ty to th li ing cyto- pla m at the animal po l

In ect egg also contai a large tore of y lk wh ch occ p e the c t r f th el gate ells, a d i rr nded by th n layer of li ing cyt pl m onta ni g th egg pr n cleu Following f til za t n th lei al ne di ide and m e apart in the layer f cyt pla m aft ea h di i n so that they d tribute them el es ll a u d th gg After nin uch nucleu div ns ha e take pl ce (p odu ng 51? nu le) the cytopla m lso cl a es t the n xt d vi i f rm ng a ingle lay r c mposed of bout 1000 c lls surro d ng th entral y lk ma

Blastula stage Am ng all the i ert b ate f m xc pt the n ct the res lt f tx to t le es y l ag cycl s th f rmati n of a phe (l las- t la) c mpo ed of mall cells wh ch l e n ingl omp ct lay r ar nd a nt l c vity (l la to- coel) If th egg has conta ned r lati ely l ttle y lk the bla tocoel i rather larg (F g 4f) while t may b erv m ll if the egg includes mu h yolk (Fig 4g) and l ttle more than lit n the pu d bla t l (F g 4h)

Gastrula stage Th e d of th brief bl tula stag oc r when the pr ess of ga t lation be- gi In t mplest f rm thi c n i t n an in d nting (i vag nati) of th bla tula w ll in th eg tal g n (F g 5a) Mea wh l ll di i i n s g g on t dily a d ance th larv h s as yet no way f tak ng in l d food f m tl e ut ide all th f rm cha es wh h o d ring th s p r od ar mpli hed with the m t ial or gi lly p e nt n the f t l ed gg The only ad i t n is w t r (bl stoc l flu d) a d h d ss l ed sul tan m tly lts f o th nment s n t th gh th ll membra es A the bl t m becom malle d the bla tula wall po d i gly thi ll a p o ded i e t d th ge t f nd tat n nt a p ket (F g 5b) With the apj ra f thi tru t e (p mitt d est e tra t) the l rva bec mes two-lay ed

Fg 2 ( ) Electro m crog aph of s ct o through face of nfert l ed s a ch n egg (*Hem t f s*) (b) Electron m c og ph of fert l d *H m t f s* egg surface

has entered a small bulge of hyaline cytoplasm the fertilization cone is f rmed and the perm tail gradually disappears into the cytopla m through thi cone (Fig 3*c*)

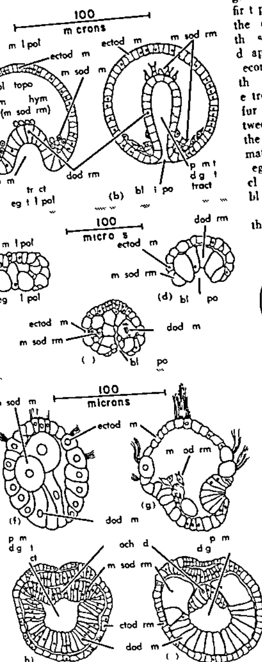
The separated meml rane continue to expand for a minute or two During this period the ul tance relea ed from the cortical granule and di lved in the fluid immediately surrounding tl e egg unites with calcium from the ea water and form a com pound which accumulates on the inner urface of tl e lifted membrane This i now called tl e fertili zati n meml rane and the added material strength en it o remarkal ly that it i al le to r si t di s l ing acti n of all kind xcept that exerted l y a part cular enzyme which the sea urcl in larva synthe izes when it i ready to hatch

The new egg surface replacing the elevated itel line meml rane follows the highly irregular c nt ur of the pocket which formerly held the c rtical granule (Fig ?l) The second component f the granule which wa left l el ind in these pock t gradually moves outward witl in a few minute after f rtilizati n Taking up calci im from th medium tl ub tance f rms a hyaline layer cl e to the egg surface which is without a bounding membra but is supported by delicate cytopla mic pro ec tions This layer holds the bla tomeres toge after cleavage and acts as a protective co ering after the larva has left the fertilization membran

While the e changes are occurring at the urface the sperm head is carried a short way into the egg cytoplasm For some three minute it i po l to distinguish it among the granular inclu ion in very transparent eggs After thi and while part of the tail is till outside the e g the perm nucle begins to swell and can no longer be recognized in living eggs Within two more minute a halo of hyaline rays begins to appear in thi region This is the sperm aster (Fig 3*c*) formed by the egg cyt plasm under the organizing influence of the perm centriole

Fg 3 Fe t l ton of th s a chin egg (a) Forty o ds aft i m at o Sp m h ad beg ng to e te cytopl m f t l z t o m mb a e l ft d round p m e t a c po nt (b) Th e mi ut fte i em no to F t l t o m mb a f ee a d gg rface f t l zat co fo m d (c) F mi t s Sp m a app g e d of p m t il abo t to t egg (d) S mi t s Sp m a t e l gi g mo i g toward c t f gg f rtl z t co d pp ari g (e) E ght m t s Egg p cl m g tow d c ter f p m a t p m p cl i bl (f) Te mi ut Sy gamy c mpl t p m f ll g cytopla m

ed ry car fully o th t th ir life his-
f lly k wn A f w of these w ll be out
n f ll w ng ct ns

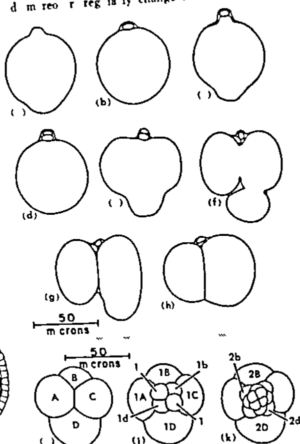


Fg 5 G t l h d l rv l m d m f m t ( ) E ly tag y lky ggs. (b) L t tag y lky gg ( ) L t bl tul y lky gg f th sn l Litt (d) E ly g tr l i y lky gg f Lit t ( ) L t g t l y lky gg f Litt (f g) P t ll th l mp t m sod m f m t cti th gh t f bl tul d t h ph larv (h) C ss sect f Amph mbry mm d tely ft g l t ( ) C ct f Amph m

MOLLUSCAN DEVELOPMENT

Fertilization and cleavage The eggs f *Myt lus* the c mm n m el are fertil zal le ju t after the germinal icle br aks down (Fig 1d) A the fir t p lar body i gi en off fr m the animal pole the eget l urface f tl e egg bulges ut t f rm th so-called polar l be (Fig 6a–d) The bulge d app ar h rtly t reapp r at the time f econd p lar body formati When the egg cl a es th eg t l cyt pla m i egregated into a m re e trem polar l le (Fig 6e f) and th clea age fur w d de the rem ning material equally be- tween t o l la t me e Th c t i t n f rm ng the pol r l be d appe r retu rn ng tl e polar lobe material to on f th bla t me es (F g 6g,h) The eg tal mate i l i again s gr gated at th second cl a age nd aga m xed with ne f th f ur bl t me es

It i ha act ri t f thi type f clea age that the m t ti pi dles l e a lant i the l la t m res d m reo r reg la ly change the direct n f



Fg 6 M tu t d ly l g l th m l *Myt l* ( ) F rst p l body b i g fo med at l m l p l p l l b t g t l p l (b) F rst p l b dy mpl t ly t d d p l l b w thd w (,d) S d p l b dy f rm t (,f g) F rst l g (h) Two-c ll t g ( ) F -c ll t g (j) E ght-c ll t g f rst q rt t f m m (1 1b 1c 1d) (k) S t -c ll tag w th th q rt ts f m m

an outer layer the ectoderm which will later produce the nervous system as well as the outermost body covering and an inner layer the endoderm from which will be formed the lining of the functional digestive tract and its associated organs and glands As the primitive digestive tract extends into the blastocoele its opening to the outside becomes smaller and is known as the blastopore

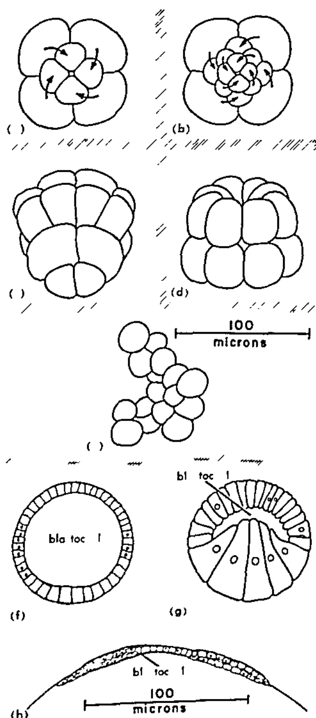


Fig 4 Symmetry of cleavage patterns and invertebrate blastulae (a b) Spiral cleavage (c) Bilateral cleavage (d) Radial cleavage ( ) Irregular cleavage (f) Sea urchin blastula Relatively uniformly sized blastomeres and large blastocoel (g) Annelid blastula Blastomeres at vegetal pole large yolky; small blastocoel (h) Squid blastula Blastomeres in animal pole region only slitlike or no blastocoele

A modification of this process of endoderm formation occurs among some species having large yolk filled vegetal blastomeres (Fig 5c) The small actively dividing cells of the animal pole region spread down to cover these more inert blastomeres (Fig 5d) which become the endoderm and later form the digestive organs while the overlying ectoderm leaves a small opening in the vegetal region which corresponds to the blastopore (Fig 5e)

Mesoderm formation At this time the first few cells belonging to a third body layer the mesoderm, make their appearance by slipping from the ectoderm layer into the blastocoele These early mesoderm cells are of a primitive sort (mesenchyme) possessing pseudopodia and often moving about freely between the ectoderm and endoderm. In sponges and coelenterates no more highly organized middle layer is formed even in adult animals but in the other phyla the so-called true mesoderm is endodermal in origin either being formed by successive divisions of a cell which originally belonged to the endoderm (Fig 5f g) as in annelids and mollusks or separating off from the primitive digestive tract as in *Amphioxus* (Fig 5h i)

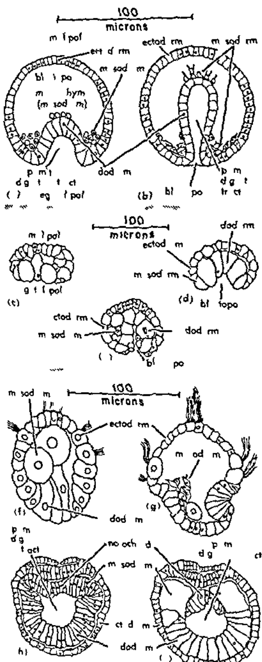
In either case this mesodermal tissue spreads out between the ectoderm and endoderm and in all phyla more advanced than the flatworms splits through its center into an inner and an outer layer The cavity thus formed within the mesoderm is the true body cavity in which the various internal organs lie The outer layer of mesoderm becomes closely applied to the inner side of the ectoderm forming body wall muscles and other supporting layers while the inner layer of mesoderm surrounds the endoderm with layers of muscle The organs of circulation excretion and reproduction as well as all muscles and connective tissue are eventually formed from this mesodermal layer

Later development So far it is possible to summarize the development of invertebrate animals as a group but beyond this point each subgroup follows its own course and these are so widely divergent that every one must be considered separately Meaningful generalizations are not even possible within a single class in some cases as attested to by the various modes of development occurring among the Insecta some of which proceed directly from egg to adult form while others go through an elaborate series of changes *See* INSECT PHYSIOLOGY; INSECTA

In very many species there is a sharp break in the life history when the larva after passing through a number of morphological phases which lead from one to the next with a steady increase in size and complexity abruptly forms a whole new set of rudiments of many adult organs which take over the vital functions This metamorphosis represents the end of the larval period The tiny animal which it produces is for the first time recognizable as the offspring of its parent

For more or less early trying to ... the developmental process of certain invertebrate forms ...

b en tud ed very caref lly that their l fe his tor e ar fully known A f w of th will be ut l d n the f ll w ng e ti ns

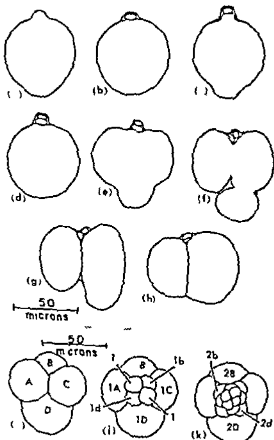


Fg 5 G tr lat d l rv l m od m f m i ( ) E ly t g i n y (ky egg (b) L t t g Jn y lky gg ( ) L t bl tul l yolky egg f th l Litto (d) Ea ly g t f l y lky gg f Lit t ( ) L t g t l y lky gg f Litt (f g) P t ll th l mp t m od m f m t o ct o th gh t of bla t) d t h ph l rv (h) C sect l Amph mbry imm d t ly ft g t ul t (') C sect o l Amph m bry som wh t l t

MOLLUSCAN DEVELOPMENT

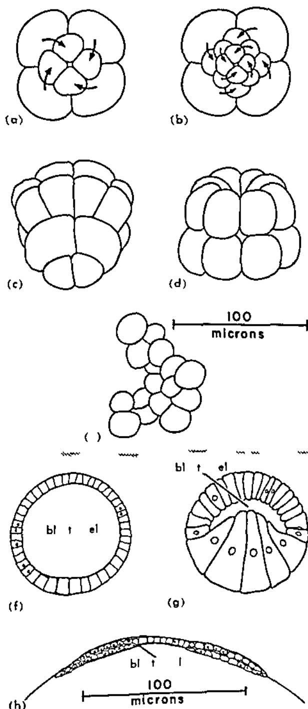
Fertilization and cleavage The eggs of *Mytilus* the common mu el are fert l zable ju t after the g rminal ve i le bre k d wn (Fig 1*d*) As the first p lar body s gi en ff fr m the animal pole the vegetal surfa e of the egg bulge o t to form the so- alled polar lobe (Fig 6*a*–*d*) The bulg di appe h tly t r app ar at the tim of e nd pola body f rmat n Wh n the egg clea es th v g t l yt pla m i s gr gated into a m re e t em polar l be (Fig 6 *f*) and the clea ag furrow d id the rema n ng mate i l e j ally be tw en two bla t me e Th c n tr ti n f rming the pol lobe d app ars retu ni g the polar l be m t rial to ne of th bl t me es (F g 6*g*,*h*) The eg tal mat rial i aga n egr gated at the se ond cle age a d aga n mi ed w th o e f th f ur bla t me es

It i characte i tic of thi typ of cleavag that th m t tic p ndle he a lant in the b la t m res nd m reover r g larly cha g the directi n of



Fg 6 M t t nd e ly l ag in th mu l *Myt* ( ) F rst p l body be g f rm d at m l p l p l be t eg t l p l (b) F rst pol body mpl tely t d d p l l be w thd w (d) S c nd p la b dy f m t o (f g) F t l g t g first q art r of m me s (l) 1b 1 1d) m e *(h)* Two-c ll t g (') F -c ll st g (j) E ght-c ll *(k)* S te -c ll tag w th th qu t t of m o-

an outer layer the ectoderm which will later produce the nervous system as well as the outermost body covering and an inner layer the endoderm from which will be formed the lining of the functional digestive tract and its as ociated organs and glands As the primitive digestive tract extends into the blastocoele its opening to the outside becomes smaller and is known as the blastopore



Fg 4 Symmetry of cl av ge patter s a d i e te brate bl stula (a b) Sp ral cl av ge (c) B lateral cleavage (d) R d al leavage ( ) Irreg lar cl a age (f) S a rch blast la R l t ely un f mly si ed bla t mer a d la ge blastocoele (g) A l d bl st la Bl st meres at eget l s d la ge yolky sm ll bl sto coele (h) Squ d bla t la Bla t me In a imal p l reg n only sl tl ke o no bl sto el

A modification of this proce of endoderm fo mation occurs among some species having larg yolk filled vegetal blastomeres (Fig 5c) The mall actively dividing cells of the animal pole regi n spread down to cover the e more inert bla tomeres (Fig 5*d*) which become the endoderm and later form the digestive organs while the overlying ectoderm leaves a small opening in the vegetal regi n which corresponds to the blastopore (Fig 5e)

Mesoderm formation At thi time the fir t few cells belonging to a third body layer the mesoderm make their appearance by slipping from the ectoderm layer into the bla tocoele The e early mesoderm cells are of a primitive sort (me enchyme) pos essing p eudopodia and often moving about freely between the ectoderm and end derm In sponges and coelenterate no more highly organized middle layer is formed even in adult animal but in the other phyla the so called true me derm is endodermal in origin either being f rmed by successive divisions of a cell which originall belonged to the endoderm (Fig 5*f*,*g*) as in an nelids and mollusks or separating off from the primitive dige tive tract as in *Amphioxus* (Fig 5*h* *i*)

In either case this mesodermal tissue preads out between the ectoderm and endoderm and in al phyla more advanced than the flatworms plit through its center into an inner and an outer layer The cavity thus formed within the me oderm is th true body cavity in which the various internal or gans lie The outer layer of mesoderm become closely applied to the inner side of the ectoderm forming body wall muscles and other supportin layers while the inner layer of mesoderm surround the endoderm with layers of muscle The organs c circulation excretion and reproduction as well a all muscles and connective tissue are eventuall formed from this mesodermal layer

Later development So far it is po ible to um marize the development of invertebrate animal a group but beyond this point each subgroup fo lows its own course and these are o widely di e gent that every one must be considered separatel Meaningful generalizations are not even pos ib within a single class in some case as attested to b the various modes of development occurring amor the Insecta some of which proceed directly fro egg to adult form while others go through an ela orate series of changes *See* INSECT PHYSIOLOG INSECTA

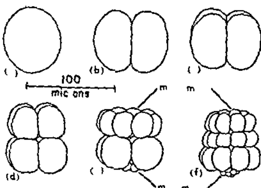
In ery many species there is a sharp break the life history when the larva after pa n through a number of morphological phases whi lead from one t the next wit a steady increa e size and c mplexity abruptly forms a whole ne set of rudimentary ad lt organs which take o er t vit l function This metam rpho is repre ent t end of the larval period Th e tiny animal which produces i f r the f r t time recognizal le as t off pring of it parent

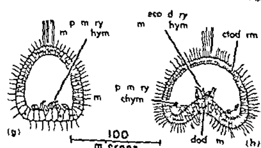
For m re or le arl itrary rea on the develo ment l proce e of certain in ertebrate form ha

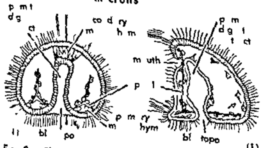
U haped w th the mouth and anu epa ated from ea h ther o ly by the f ot there ı a udden pe riod f unequal growth n th tw des f th larva o that th anu ı mo ed ar und t pen on ıts neck (Fig 7) Fye and tent le ha e alre dy b en f m d and fi ally the young animal dı a ds ıts c l um be ng elum nd tak s up the adult hab t of r p g bout on ıts foot

SEA URCHIN DEVELOPMENT

Fertilization and cleavage The fi t and econd l a a pla s d ıde th fert l zed egg (e F g 3) nt f ur q al bl stom res ınter ect ng ea h ther at r ght gl s th ough th nimal ege-tal x Th thı d l a e cuts thr ugh tl e e four bl t mere h z tally The f rth clea age pla d vide the upp r four cells nto ıght equal







Fg 8 Cl g d g st l t th a h ( ) Zyg t (b) Tw -c ll) g ( ) F -c ll ı g (d) E ght-c ll st g ( ) S t -c ll ı g (f) Th rty two-ll g (g) Veg t t g f bl tul flatt ed p m ry m hym c bl) l (h) B g g f g t d ry m hym c ll p p g bl t oel (ı) P m t d g t t ct d pe g b g g f p le f m to (j) L t g l f om de

s zed mesomeres and the low r gr up ınt f ır ery mall mı m res at tl e vegetal p le and f ur large macr meres (Fıg 8) Tl e e 16 l la tomer are each d ıded about equally at tl e fiftl cl avag f rm ng 3 c ll l ut tl e eight micromere fa l t dı ıde at the xth clea ag so tl at ther are 56 ın stead of 64 bla t eres at this tag lly r m ıng certaı of these l la tom res (ı ch as tl micro-m res) and f ll wing the later devel) ment ıt ha been f und that the eıght m cr meres of the 5(cell tage gı r t the fir t gro ıp of m en hyme cell the rıng of e ght cell ju t abo e them pro-du e me encl yme and e d derm and all tl oth r bla t mere f rm ect d rm

Blastulation The l l ı m re *continue to d ıde* s cces ıvely f rming the h ll w pl e e f the l l -tula tage B the tenth cleavag (Fıg 8f) eacl of th thou a d o l la tom re ha de el ped a c l um, nd the bla tı l h s also secr ted en ugh hatchı g enzyme to dı sol e th fert l zat m m brane Aft abcut 12 h urs f devel pm nt at 20 C the larva begın ıts free wimming per od

Gastrulation Shortly afterward the larva lon gate som wh t t wa d the an mal pcle where a tuft f l ng ımm bile cilia appe r and fl tt n n the vegetal d J t bef re ın gınat n beg ns the cell de c nded fr m the eıght micr m res l p t of the getal bl tular wall ınt tl e l l toc l (F g 8g) form ng tl e primary mesenchyme c ll

Th ga tr l t ge beg ns about 20 l ur after f rt l zat n whe the ent r f the getal wall bulges ı ward (F g 8h) Mo t f th c lls wl h form th s pocket will be ome *endode m l ut the e* re al o ome m e chymal ell *among them* (ec dary me e chyme) wh ch w ll devel p p e do-pod a that t t h acr s the bla t coele and mak ın c ntact w th th pp te body w ll *direct the* ınwa d xpan ı n f tl primıt ve digest e tr ct (Fıg 8) A thı d er n the p m ry *mesen* chyme cells re bu ld ng c lc reous pı ules with l m t k n from the e wate The skeletal r ds t d ın three d ection f m two point be ıd the bl st po and a th lengthe th dete m e tl e ch racte tıc h pe f th uc eed ng l rv l st ges (Fıg 8j)

Pluteus stage *I* th pl t us tage (F g 9a b) m uth p n ng ı f rmed wl th tıp of the f m t e d ge tı e t act) n the body w ll The t act beg n t *funct on nd the bla topore* ch ged ınt a an s th larva ı able f r the fir t tıme ı tak food from t d S e DEU TEROSTOMI

Metamorphosis D g th m nth wh h tl e l rv p nd pl t us tl e body crea e mark edly ın s e and t o mo p s f rms r add d c lled the ecl nu rud m nt f ms the b g nıng f the dult g n ystem W th n a l tı ly hort t m mo t f the larval b dy n rp r t d nt thes org ns wh h a e c gn zable as those f a yo ng a chın It m tamorphosıs ıs com plet wl ıt ca ts off the u usable p rt of ıts larv l k let n (Fıg 10)

their slant by 90 at each division so that a spiral pattern of blastomeres results Such spiral cleavage is found in the mollusks and in the flat round and segmented worms

Since the animal vegetal axis is easy to recognize in such eggs it has been possible to record the course of cleavage very accurately and to deter mine the role of particular blastomeres in normally developing embryos The four cell stage blastomere containing the polar lobe material is designated as D and proceeding in a clockwise direction the others become A B and C (Fig 6i) At the third cleavage these divide very unequally (Fig 6j k) into four large vegetal macromeres (1A 1B 1C and 1D) and four micromeres at the animal side (1a 1b 1c and 1d) *See* CELL LINEAGE

Blastula stage After two more such unequal di visions the resulting 28 micromeres have formed a hollow blastula with the four macromeres 3A 3B 3C and 3D at its vegetal side These then extend into the blastular cavity where their descendants will form the digestive tract except for one of the D daughter cells produced at the next cleavage 4d which is set aside as the mesoderm mother cell (Fig 5*f*)

Trochophore stage During the succeeding cleavages some of the cells develop cilia the blas tular symmetry becomes bilateral instead of radial and the micromeres extend down almost to the vegetal pole thus covering the macromeres except at the small opening of the blastopore After 24 hours of development the cilia are organized into an encircling girdle and an apical tuft at the a i mal pole and the larva now called a trochoph re begins its free swimming stage (Fig 7a) The blastopore is shifted forward by the fa ter pro liferation of the ectodermal cells of the other side (Fig 7*b*) and then closed but the larval mouth is later formed at this place (*see* PROTEROSTOMIA) Behind it the endoderm forms a stomach and a narrow tube gradually extends from this to make the intestine The anus forms later at the place where the intestine reaches the ectoderm

At this stage a group of ectodermal cells is form ing the shell gland which will secrete the hell (Fig 7*c*) Two small protuberances will unite and develop into the foot and a pair of elongated pit beside the mouth will form the balancing organs The 4d blastomere has cleaved into two cells l cated on either side of the mouth which are gi ing rise at this stage to two rows of me oderm cell called the mesodermal bands

Veliger stage Within a week the hell gland ha grown and begun to secrete the shell and the foot is projecting prominently The stomach increases in size and bulges into the shell cavity and cell from the ends of the mesodermal bands form mu cular attachments for the stomach and e ophagus The girdle of ciliated cells (velum) enlarge and the rudiments of a nervous system including eye cups appear near the apical tuft The larva is now called a veliger (Fig 7*d*)

Metamorphosis Following further development especially of the alimentary tract which becomes

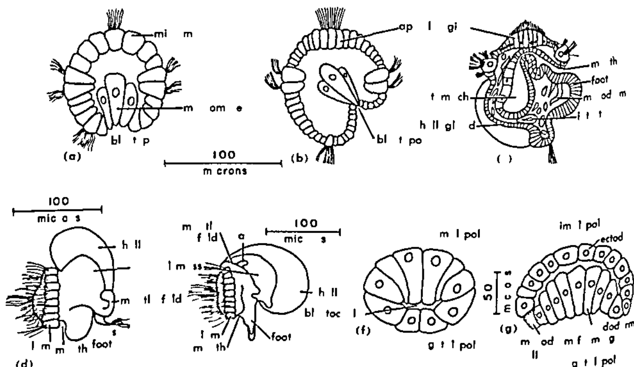
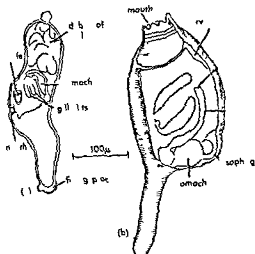


Fig 7 Stag s i the dev lopme t of *Pat ll* a d gast l t o in a tu lcate (a) Lat bl st la of *Pat lla;* macromer s being co e ed by microm es blastopore at veg tal pol (b) Ea ly t ochopho e of *Patella;* blas topore h fted forwa d ( ) M tu ed t ochopho e larva of *Pat lla* (d) V lig la of *Pat ll* ( ) L te el ge stage of *P t lla* Twi t g of body h s ca d m tle f ld a d p t o f an f rwa d a d tu n d h ll about (f) Late bl st la of t icat mbryo (g) B g i g of g t lat o i t icat embryo



Fg 11 M t m rph t t ( ) Beg g f m tom ph (b) Yo g d lt

mt t e f g t f s w th th e t derm t op n s a nu a d f rm a t ma h and a h e l ke gl nd

A culat ry sy t m wh ch wa started d ring the t dpol t ge d el p a m cular heart. F ur n w pa of gill lits p n s to th pharynx The e l t d ide a d g t furthe ws of mall r lit Th epr duct rg ns re f med from tw m sses of m derm c ll ly g ne r th ph r ynx. These dev l p nto an ary nd t stis

[J C D]

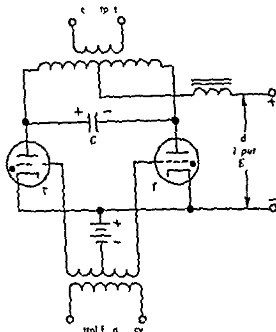
Inverter

A dev ce fo n ert ng di ect c r e t (d) i t alt at ng u r t ( ) F r low power qi e me t t may be n electr mechan l v b ator wh ch u es nta ts n a b ating a mat r to r ers th pol ty f th d rect urr nt at a rat o resp d g to the d s d a fr q en y (s e VIBRATOR) Such in t r re ed in utomob les t ba g th torage b ttery lt ge t 115 volt alter nating u nt f op at g a p bl c add y t m t pe ecord r o the a equ pment i th car Th e all d el t ni i ert r A el tric r t i ng m h n th t e rt d i ac i l all d n e t (e CONVERTER SYNCHRONOUS) Th type f i rt r s ft n u ed c ft For la g r p w r req i m nts the r v r al f p la ty t r g l r int rval s d e w th thyr t gm t o tl l t o d e th t d t h c nta t g p bl m [J ER]

Thyratron inverter A p tely ited pa all l thy tr nv rt i it h n in the fig r A ntr l s g al bta ned f m n ext rn l applied t the grid n a symm t al on ect o h wn

Ngl ect ng th t be d p nd a m ng that th right h d t be T h s fi ed th f ll d upply lt g E pp a the p t C w th th l ft h nd id ha ged po t ly d cated D r ing the ne t half-cycle when th control v ltag on tube T_2 bec mes positi e en ugh T_2 fires. This cau es the voltage $-E_d$ to appe r acr s T_1 and T_1 i extingui hed Then C i ch arged through T_2 t th v ltage E_d but with th oppo it polar ty to that how

In the foll wing half-cy l T fires T_2 i xt n g i hed nd C recharg through T_1 to the polar ty shown in the figure Th abo e cycl of events is r peated w th a frequency equal t that of th con trol s gn l



A ep t ly-e t d pa ll l thy t i vert i t

If the lo d is res sti e a d he y the utput volt ag has a square wa efo m For a l ght resisti e load the output h a tria gular wa e hap For an indu tiv load a sinusoidal wa ef rm output may b obta ned

It i po ble to l m nate the extern l ac contr l signal by obt n ng the grid ltage from the out put pl te c cu t. Such a c nfiguration i called a s lf e c t d in ert S e OSCILLATOR [J MI]

Involute

A t rm appl ed t a urve C that ts at ight ngles all ta g nts f a curve C Ea h rv C ha i finit ly many i v l t s and the d tan e betw e corre spo d ng p t f any two in l t s is co tant If $x = x(s)$ w th $i = 1\ 2\ 3$ a e paramet c eq t ons of C with par m ter r length n C all inv l tes C f C ha param t equ ti n $Y_i = (s) + (k - s)x'(s)$ with $= 1\ 2\ 3$ wh e $x' = dx_i(\ )/ds$ w th $i = 1\ 2\ 3$ a d k de ote n a bi tr ry c nsta t L t l ngth of tr ng be ne de t w th a curve C w th o e e d fa t ned at a po nt P f C If th st g i unw u d ma n g ta t, the th d of th tr n i c ni l t C of C

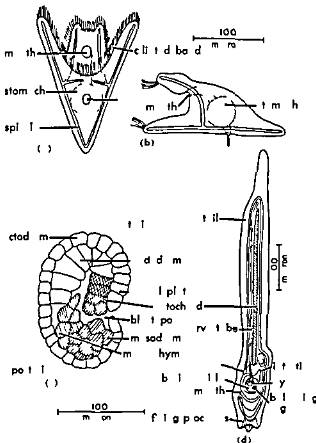


Fig 9 (a) Pluteus stag of sea urchin larva ventral view (b) S de view ( ) S ct on th ough tun cate gas t la (d) Tadpole st ge of t n cate l rva

TUNICATE DEVELOPMENT

The fact that certain structures characteristic of vertebrates and found in no other invertebrates *appear during the larval life of the tunicates forms* the basis for giving these otherwise unprepossess ing animals their high status at the top of the in vertebrate subkingdom and makes them especially interesting from the evolutionary aspect

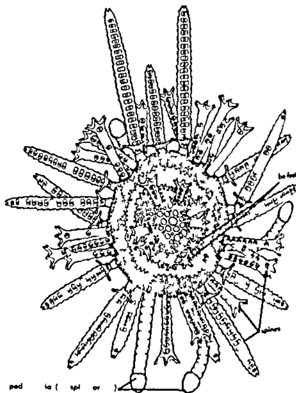
Fertilization The eggs of the tunicate *Styela* be gin meiosis as they are laid going as far as the metaphase of the first reduction di ision where they stop until they are fertilized The spermatozoon penetrates *the thick chorion* enters the egg at the vegetal pole and stimulates it to proceed with meiosis While the polar bodies are being given off cytoplasmic streaming segregates the cell compo nents into a yellow pigmented region a clear yolk free region and a gray yolky mass It is possible to recognize these differently colored materials later in development and determine the role of each in body layer formation

Cleavage The first cleavage divides the egg into similar blastomeres Becau e of the arrangement of the colored cytopla m it l ilateral symmetry is already visible The 16 cell stage consists of two layers of eight cells each (Fig 4*h*) with tl e yell w cytoplasm contained in four of the vegetal cell At the stage with al ut 40 cells a l la tula is formed The prospective ectoderm making up it animal side consists of thick columnar cells while the future endoderm cells at the vegetal side are rela tively flat (Fig 7*f*) This difference is reversed be fore gastrulation begins (Fig 7*g*)

Gastrulation The gastrula is formed by the movement into the blastocoele of the vegetal id cells followed by an overlapping growth of the prospective ectoderm Within this enveloping layer the yellow cells produce mesoderm the other vege tal cells form endoderm As the ga trula devel ps the surface layer anterior to the blastopore (Fig 9*c*) forms neural tissue which is organized into a brain and spinal cord while the mesoderm beneath it forms a notochord a precursor of the vertebral column characteristic of vertebrate animals This notochord elongates as the axis of a tail and the larva hatches from its chorion and begins a free swimming stage

Tadpole stage During this stage (Fig 9*d*) the tadpole acquires an extensive but nonfunctional digestive tract two pairs of gill slits (also char acteristic of vertebrates) a cerebral eye and a balancing organ At its anterior end it has three papillae with which it will fix itself to a substratum when its short tadpole stage ends

Metamorphosis When metamorphosis begins (Fig 11) the tail ectoderm contracts strongly *bending and breaking up the notochord* nerve cord and tail muscles which are consumed by phago cytes The chin region next to the organ of fixa tion elongates greatly carrying the mouth upward A new nervous system replaces the larval one The



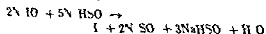
F g 10 Y u g chi o d (P o ella japo c) afte met m pho i (F m K Oka ok a d J C Da M ta m ph s of part al larv of P o ella japo ca M f a s d dollar Bi l B ll 106 83–99 1954)

I d n i tial to h gh r anum l a d t d zed alt (co ta n g od m or pots ium i d des) i w del u ed t a u e an adeq ate d etary s pply of iod ne S NUTRITION THYROID LA D

T mp rtant d tr al u of iod ne are n (1) ph t g aphy wh r l er od d ed s a n t tu nt f fa t ph t g aph c film emul i a d (2) the dye i du try wh re i d e i a n t tu nt f a umber of imp rtant dy See DYE ..OTOGRAPHIC MATERIALS SALT (FOOD)

Occurrence I d n w d ly but rarely n i gh n t t d ne er i l m t l form th g e t atn n the th c u t ha be n e tim ted t be 0 3 pa ts p r mill on (ppm) i d the nt at n i se wat r s about 0 05 ppm Th m t imp tant r e f iodi e th od um n tr te dep it f Ch l i whi h odi s a al m i d te ntrat o of b t 0 1% d e by w ight. A tl mport nt r of d is tan l w ll b ines f Californ a and Jap wh e n t at s n th nge f *50-100* ppm f d In th e br od ne o ur th od d n I

Recovery and production Mo t f the w ld t l pply m f m th Chilean depo ts So- l t o tan g the d t e du l w th sod um bi lfit to p t t the i di *The pre* p t t d d p r fied by s bl m t n

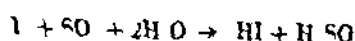


$$2NIO_3 + 5NaHSO_3 \rightarrow$$

$$I_2 + 2Na_2SO_4 + 3NaHSO_4 + H_2O$$

I th U ited St tes *bst nt al p rt o* of the od umpti ppl d f m d m t il b i Th p p l c e m thod *in* e n l d t f tl i did n t f ee od with hl d m al f th latile *od ne* fr m s l ti w th a t eam f a Th od abso bed n l t d d ed t hydr od d th lfu d de

$$I_2 + SO_2 + 2H_2O \rightarrow 2HI + H_2SO_4$$



Thi lut i hl nated t p pitat f od whi h i pu fi d by tre tm t w th n nt ated sulf d

In th p t od h bee l t d f m ert f m f weed th a h f wh h c t n p t 0.5% d d by w ght nly a m n amo nt f od e bt i d f m thi u

Physical properties Only one i t pe f i li e occur n t irally th t f ma n mber 127 (53 pro t n 74 neutr n) O er 22 a tif al isot pes l a e been pr pa ed f whi h the mo t important i 1 with a half lif f 8 day Thi ot pe ha f ind con d af l u in radi a ti tracer w rk S TRACER RADIOACTIVE

Th mol c lar f rmula of odi I_2 n the lid l quid and ga eou tates alt gh at tem peratu es of se ral hundred d grees C di socia t n of the molecul int atom becomes appr i able

I d ne i moderat ly sol ible in a numl r f n n pol r sol ent ich a ca bon t tr hl ride and aliphat hydr carbon Thes lut n p es tle ame hara teri ti vi l t l r a the vapor h w ng th t in these l ents iodine reta n it d at m c tructure Iodine i m t lul l in ar m t hydro c bon a d ygen c ta ni g orga ic sol ent such a al oh l and ester with wl i h the iodine form molecular complexes Soluti s in aromatic hydroc l ns a r d nd lution in xyg n co ta n g sol ents are l rown Alth ugh iodin i only i ghtly sol l l water g i g l rown l i t n ti xtrem ly ol l l in ol iti ns c nta ng ol bl odides becau e of tl e f rmat n of deep b wnt l l ck c mplex polyiodide on

Chemical properties In its l m cal pr p rties dine es mbles the the m mbe s f th h l gen fam ly H wever iod ne the lea t electronegati e f tl e hal g n tl at is it exhil its tl e le t te d y to cqu re n electr n to c mpl te its oct t f le e elect n A a re ult it i the le t re- a t hal g n tl e easie t to oxidi e and f rms the w ake t bond with th mor electropo it e elem nts

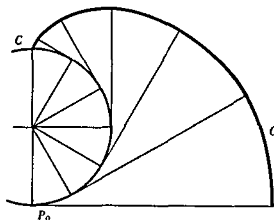
Iod ne f rms comp und w th all of the eleme t x pt the n ble g e lfu a d el nium It e t d r ctly with m t elem nt xc pt c rb n t gen o yge and me of tl e n bl m tal

I di e l eats s d th th r l l gen w th n mbe of o gan comp nds In general tle act ns w th iod n are l s ig us and may n t p oceed t an app eciabl xtent u les a y hy dr g n iodide HI which i f rmed is cont n ou ly rem ed Am g the typical a t ns f iodine w th o gan mpou d a e th react on with b- t tuted a mat cs to form aryl od de the e t on w th c rbo yl compou ds to d t the carbon adj t to th ca bonyl a d tl add ti n to mul t pl bo d of n t ated hyd oca bons

Iodi i aq eou s lut n i edi ced t iod de ion I by good educ g agent su h a s lfu

Som import t physical propert es of iodi

At m w ght	1 0 91
Spec f gr vity 0/4	4 930
M l po t C	113 6
B l g po t, C	18
H t f f n, cal/m l	3770
H t f po t l/m l	9970
Sol b l ty w t g/1000 g (0 C)	0 9



An involute C' of curve C

By varying the length of the string all involutes of C are obtained. See ANALYTIC GEOMETRY.

[L.M.BL.]

Involutional melancholia

A severe depressive reaction occurring at the time of the female climacteric and during the corresponding age period in men. It is characterized by symptoms of sadness, anxiety, guilt, and low self-esteem similar to the depressed states of manic-depressive psychosis. Patients often have hypochondriacal and nihilistic delusions; a combination with paranoid reactions is not infrequent. Usually such patients do not exhibit any intellectual deterioration (see MANIC-DEPRESSIVE PSYCHOSIS).

The etiology of the disorder is unclear. Endocrine processes seem to be of importance, but detailed evidence for such an assumption does not exist. Organic mechanisms are probably similar to the depressive states in manic-depressive psychoses. Psychological observations have shown that most involutional depressions react to real and imaginary deprivation of love and esteem with severe depression. Often a deprivation of a similar type can be detected in an analysis of the patient's relationship with his mother during his infancy and early childhood.

In the differential diagnosis, organic reactions, presenile disorders, paranoid states, and schizophrenia need to be considered. The differential diagnosis of neurotic and reactive depression may be very difficult (see PARANOID STATE; SCHIZOPHRENIA).

Electric convulsive treatment, tranquilizing drugs, and psychic energizers in combination with psychotherapy are the usual methods of treatment. In mild cases electric convulsive treatment can and should be avoided. Hospitalization is usually indicated, and the prevention of suicide and self-destructive behavior is particularly important. See PSYCHIC ENERGIZER; PSYCHOTHERAPY; TRANQUILIZER.

[F.C.R.]

Bibliography: J. R. Ewalt, E. A. Strecker, and F. G. Ebaugh, *Practical Clinical Psychiatry*, 8th ed., 1957.

Iodate

A negative ion having the formula IO_3^- and derived from iodic acid, HIO_3. Some salts such as $KH_2I_3O_9$ and $KH(IO_3)_2$ indicate that the acid may exist as polymers of the ion indicated by the empirical formula. Sodium and potassium iodates are the most important salts and are used in medicine.

Iodates occur along with $NaNO_3$ in Chile saltpeter. They are prepared in an electrolytic reaction similar to that for the preparation of chlorates or by oxidation of iodides with chlorine.

The iodates are more stable and are weaker oxidizing agents than bromates and chlorates. See BROMATE; CHLORATE; IODINE.

[E.E.W.R.]

Iodide

A compound which contains the iodine atom in 1− oxidation state and which is derived from hydriodic acid, HI.

The chemistry of iodine and its ability to form covalent and ionic iodides is very similar to the properties described for chloride. See CHLORIDE.

In comparing the iodide ion with the other halide ions, it should be pointed out that the iodides are more covalent, are the best reducing agents of the group, and form the least stable complexes. The aqueous solubilities of the metal iodides are much the same as the chlorides but in general a little lower. In organic solvents the order of solubility is frequently reversed. Bismuth and mercuric iodides are only slightly soluble. Iodide ion combines with free iodine to form the triiodide ion, I_3^-.

Sodium or potassium iodide is added to table salt to prevent malfunction of the thyroid gland. Silver iodide is used in photographic film and papers.

Iodide can be detected in solution by oxidizing it to the free element with chlorine. It imparts a violet color to the solvent when extracted into carbon tetrachloride. See COMPLEX COMPOUND; HALIDE; HALOGENATED HYDROCARBON; IODINE; PHOTOGRAPHIC MATERIALS; THYROID GLAND.

[E.E.W.R.]

Iodine

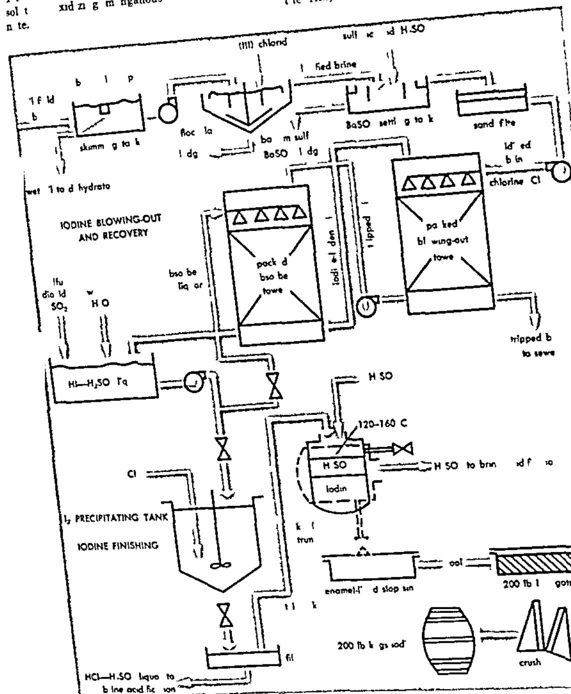
A nonmetallic element that is the next-to-heaviest member of the halogen family, group VIIa of the periodic table. Iodine, I, atomic number 53, exists under ordinary conditions as a grayish-black solid crystal of which possesses a somewhat metallic luster. Heating the solid yields a violet vapor. See HALOGEN ELEMENTS.

Uses. Pharmaceutical and therapeutic uses account for over half of the iodine consumed at the present time. One of the principal such uses is in antiseptics, but a large number of preparations containing iodine compounds also exist for the treatment of arthritis and other disorders and as aids in x-ray procedures. Increasing use is being made of compounds in the disinfection of drinking water. See ANTIMICROBIAL AGENTS; ANTISEPTIC.

? ri d e a d exi t in l t on both as th p a d H IO a d the met d HIO Th occur a e f th pa form with od ne but not with sm ll h logens i att ibuted t the la ge iz th iod n at m whi h ca acc mmodate more t m d it lf S lt f both form are k wn d a ge ally p ri gly l bl in water Th l d dec mp e n heat ng t oxygen and io- l t Th pe od tes ar powe ful idant in id sol t xid zi g m nganous n t permanga n te.

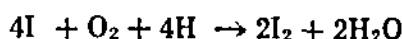
Compounds of iodine-organic There are tw mportant l es of rgan c comp und c ntaining iod ne the od des and th e in wh ch the iodine i in a pos ti o idat n stat

Iod d s The impl organic iodide resemble the other h l des in th ir pr p rties The carbo iod e bond i the w akest f the hal gen-carbon bo d a d the g c od des a e the lea t tabl and tl e m t re cti Beca e of th l e v iod ne at m th iod des are al the den est and the lea t ola t le Alkyl odides are prep ed by the reacti n f



P od ct f iod

dioxide SO_2 or hydrogen sulfide H_2S The thiosulfate ion S_2O_3 is oxidized to the tetrathionate ion S_4O_6 by iodine and this reaction serves as a basis for the analytical determination of iodine The iodide ion is easily reoxidized to free iodine by moderately strong oxidants such as ferric iron and bromine It is slowly oxidized by oxygen in acid solution



$$4I + O_2 + 4H \rightarrow 2I_2 + 2H_2O$$

In the presence of iodide ion iodine reacts with starch solutions to form an intense blue color which is often used to detect iodine in very low concentrations

Iodine is hydrolyzed only slightly in water to form iodide and hypoiodous acid in which iodine is in the 1+ oxidation state



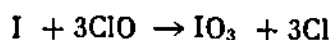
$$I + H_2O \rightarrow I + HIO + H$$

However in alkaline solution the above reaction goes completely to the right because H ions are removed to form water The hypoiodite is unstable and especially in strongly alkaline solution disproportionates further to produce the iodate ion



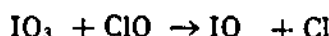
$$3IO \rightarrow IO_3 + 2I$$

The oxidation of iodine or iodide in alkaline solution with strong oxidants such as hypochlorite also produces hypoiodite and iodate



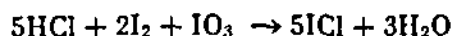
$$I + 3ClO \rightarrow IO_3 + 3Cl$$

but excess oxidant will convert these species into periodate



$$IO_3 + ClO \rightarrow IO + Cl$$

In acid solution oxidation of iodine with strong oxidants such as chlorine permanganate and iodate will produce first iodine monochloride ICl in which the iodine is assigned a 1+ oxidation state

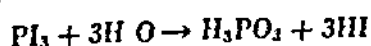


$$5HCl + 2I_2 + IO_3 \rightarrow 5ICl + 3H_2O$$

Further oxidation will convert the ICl into iodate

Compounds of iodine inorganic Iodine forms useful and important compounds with hydrogen metals the other halogen elements and oxygen

Hydrogen iodide This compound is a colorless gas with a boiling point of −35 3 C It dissolves in water at 10 C and one atmosphere pressure to the extent of 70% by weight The solution is known as hydriodic acid Gaseous hydrogen iodide can be prepared by reaction of hydrogen and iodine vapor over a platinum catalyst but is most easily prepared in the laboratory by the reaction of water with phosphorus iodide



$$PI_3 + 3H_2O \rightarrow H_3PO_3 + 3HI$$

Iodides The metallic salts of hydriodic acid are typical saltlike compound with high melting points Except for the silver lead copper(I) and mercury(I) salts which are insoluble they are generally quite soluble in water

Potassium iodide mp 680 C, solubility in water 144 g/100 g at 20 C is also readily soluble in methanol Commercially it is the most important compound of iodine It is generally made by treating iodine with potassium hydroxide to form the iodate and iodide and then heating to decompose the iodate to iodide

Some iodides such as titanium and zirconium *tetraiodides decompose to the elements at high* temperatures very high purity zirconium metal is prepared commercially in this manner

With the nonmetallic elements iodine forms typical covalent compounds such as $NI_3 NH_3$ PI_3 and AsI_5 which possess low melting points and considerable solubility in organic solvents

Iodide ion forms anionic complexes in solution with a number of metal ions and in many cases salts of these ions have been prepared for example, K_2HgI_4 $KAgI_2$ and Cs_2SnI_6

Compounds with other halogens The simplest compounds of iodine with other halogens are binary ones such as IBr and ICl which are known as interhalogens These are low melting solids with halogenlike properties Iodine also forms two stable reactive fluorides IF_5 and IF_7 the former a colorless liquid the latter a colorless gas at room temperature

A number of metal trihalide compounds such as KI_3 $CsICl_2$ and CsClIBr are known They contain a linear trihalide ion with the heaviest halogen in the center Related to these compounds are the polyiodides (I_5 I_7) the anions of which can be thought of as complexes of free iodine and the iodide ion They form stable black solid salts with the larger cations and compounds such as KI_9 have been prepared

Compounds of the 1+ and 3+ oxidation states Aside from the interhalogen type compound the unipositive oxidation state of iodine also exists in compounds of the type $I(py)_2NO_3$ and $I(py)_2ClO_4$ which contain the I cation complexed with an aromatic amine (py = pyridine)

Although 3+ iodine is not known in aqueous solution compounds such as $I(NO_3)_3$ $I_2(SO_4)_3$ and ICl_3 can be made by oxidizing or chlorinating iodine in the absence of water

Iodates and periodates The most stable and well known of the positive iodine compounds are the iodates (5+) and the periodates (7+) which can be prepared by oxidation of iodine or iodides in alkaline solution Iodic acid HIO_3 and periodic acid H_5IO_6 are stable white crystalline solids which are quite soluble in water Heating iodic acid produces iodine pentoxide I_2O_5 also a stable white solid which reacts with water to reform iodic acid Except for the salts of the alkali metals and magnesium most iodates are only sparingly soluble in water Acid solution of iodates are strong oxidizing agents being reduced to iodine or iodide ion The solid iodates are fairly stable to heat but decompose eventually to oxygen and either the iodide or the oxide plus iodine

on exchange

chem l act i wh h m b l hydrated i ns t sold re ch ged q al t f requi l nt ns (l k ch ge sol tion The sol d h an p fish tlike tru t re d the m b le s lec ri lly n utral ze ch rged r p te t lly harged gr ps tta hed t th sol d mat x c lled the t h nge Cat excha ge urs when th fi ed ch rged gr ps (funct al g up) of the ex h g eg t a exch nge occ s when the imm b l zed f tio al group e p tive Io e cha g sed f wat soften ng wate demin e lzi g parat n of s b t ces, and pu fi a t f h m cal

Eq l b a f -exch g act r usu lly p e ed by th g n ralized q atio

Catio e change

$$aB^{+b}_{( )} + bA^{+a}_{( )} \rightleftharpoons B^{+b}_{( )} + bA^{+a}_{( )} \qquad (1\ )$$

An on exchange

$$B^{-b}_{( )} + bA^{-a}_{( )} \rightleftharpoons B^{-b}_{( )} + bA^{-a}_{( )} \qquad (1b)$$

with the rrespo di g ma ct o xp es n

$$K_{AB} = \frac{[B^{+b}]_{( )}[A^{+a}]^{b}_{( )}}{[A^{+a}]_{( )}[B^{+b}]_{( )}} = \frac{[B^{-b}]_{( )}[A^{-a}]^{b}_{( )}}{[A^{-a}]_{( )}[B^{-b}]_{( )}} \qquad (2)$$

he e b kets d te the conce t at s f th h gi g o c pe ies A d B (glect g t v ty co ffi i t ffect f mpl c ty) *a* a d *b* pres t th r ch ges d d gn te the res (r h ng r) and sol t pha a d K c espo d t the n e cl g eq l b m ta t. *S* e EQUILIB IUM CHEMIC L

D ff e es ft n e t b tw n the d t b t of v u i betw e th old d l q d *pha es* (th t K l es dff f s l ct d p r of ns) *U ually* the d ff ce an bu l ged by lec t ely mpl g i i l t n d by p t g th -e cha g ea t m y times Th tech q ch g ch r matog phy s th b f m y n k g pa t pr d that e mpl yed b th lyt l h m t *Th ele-* m t to b p ted a bed f m lut n a w b d t th t p p t f i ha g es l m d th w hed d w th c lum (l ted) by p g a electi mpl g ag t th gh th l mn u til p t n h eved The n l g e t f e h n pe ted m y t mes by th p t n a d n mb ati w th th eff t f the mple ng g t lt i the p t l the indi f l el m t nt b d n th l m S CH O IATOGR PHY

Oth mporta t ppl t o f h g at ft g d the d m n r l zat n f w t l th fi t ppl t l m m gnes *m* d th u des bf t mp i es h ged l r a d m i d g p l ti f th t th ugh n e h g es n l mn th and m f *m* In th ec d ll o mp t es t ed w t a em ed by e h g f hydrogen a d hydroxyl ion du ing pa ge f th w ter uecessi ly thro gh at and ni n e cha ge re in i the acid and l a e f rm

Zeolites Tl e are natural cl y m ral which hib t io -e ch nge properties Tl ese mater al ha an open tl ee d men nal n tw k tru cture (the al mino ilicat skeleton) c tai ing reg lar ch n els t imb be wate Cat n wh h ne trali the ex es neg t e charges on their kelet n dif fu e i and t of th wate onta ed in th i ni form i te tices f the zeol te cry tal duri g n xcha ge re tio

The ex hange cap c t es of these materi ls are ally expres ed a the numl r of mill equi ale t of c t per 100 g l d y material whi h are ex hange ble in n t l lution Tl e change c p t e a well as thei c p b l ties f r ex hange differ con d r bly I the m re c mpact str t es exchange is limited t the smaller uni le t hyd ated o a d n m n ta ce n e change can occur I the ca e of rthocl (f ld spar) K O Al O 6S O f r example th p tas- m ns are impr so ed d ailal le for x hange

Oth mpl cating f tu es in zeol tes e their i t b l ty in ac d lkaline sy t m the pres ce f d ff r t tes with ry g bi d g strengths d rates f e ha g and th un rt n com *p s ti*

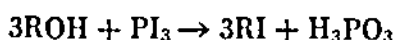
Art fi l zeol tes of well-defined compo tio e now manufa tured with p fectly form inter stice f c t oll d dime ns a d with reg l rly *d st b* ted cha ged sites which demo trat q i v ale t o ch ge beha i F a d *cus i f* the mat als ee MOLECULAR IEVE

Other t r t g inorg n c n-e ha ge *mate-* l w th both at d a on-e change p *per t e h* bee pr p red E mpl s of th e com pound a e zi co m pho phate a d zi c um o *ide whi h* when pr p red by pre pit t n fr m sol t on a d d ed t le ated temper ture be ha at nd ni excha ge r pe ti ly P e mably th p ecip tat n f *p* lym e n st tu t n soluti o p vid s n tw rk with fix d r d l h g M bile i within thi n t work n tral ze th ha ge

Ion exchange resins Thes a e m d up of thr e d m al rg c tw k n l d ng ha ged o p t *ti* lly ch rged gr p wh ch ar e t l zed by mobil n f *pp* te charg Fr ed m f th m b le r ter io to m in a d t f th r i p ded by w ter m bibed b th resi on imme n an q eou s l t Th w t pen the e t tu e perm t t g d ff i f ons to and ut f the e w t (g l) ph ed g h nge

M ny atu l p od ts e h b t ati o x h ng p p rt F r e mple the ll co t nt of pl nt t h a t ed b i h g tru t bec se f th p n of rb yli ac d g p Othe d c nt f nd a eth r l s lfate g p (—C—OSO N) c t n aw ed a bo-

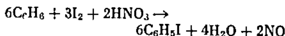
the corresponding alcohol and either HI or phosphorus triiodide PI_3



$$3ROH + PI_3 \rightarrow 3RI + H_3PO_3$$

Methyl iodide which is prepared in this manner is a colorless liquid bp 42 5 C d(20/4) 2 28 It finds some use as an alkylating agent

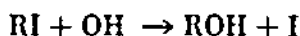
Aryl iodides can be prepared from the hydrocarbon iodine and nitric acid



$$6C_6H_6 + 3I_2 + 2HNO_3 \rightarrow 6C_6H_5I + 4H_2O + 2NO$$

Iodobenzene which is prepared in this manner is a yellow liquid bp 188 6 C mp −31 4 C d(20/4) 1 83 It can be used to prepare organic compounds of positive iodine *See* HALOGENATED HYDROCARBON HALOGENATION

The alkyl iodides are the more reactive reacting with hydroxyl ion to give the alcohol and iodide ion



$$RI + OH^- \rightarrow ROH + I^-$$

and with amines to alkylate the nitrogen atom



$$RI + R'NH_2 \rightarrow RR'NH + HI$$

Positive iodine compounds A number of compounds are known in which iodine is formally in a positive oxidation state These compounds are characteristic of iodine alone among the halogens and occur only if an aromatic or olefinic group is attached to the iodine

The first group known as iodoso compounds has the formula RIO They are formed by oxidizing the corresponding iodide with strong oxidants such as fuming nitric acid They are soluble in alcohol but not in water are good oxidants and are stable at ordinary temperatures Treatment with HCl as well as chlorination of the original iodide produces related compounds the iododichlorides $RICl_2$

A second group of compounds is the iodoxy compounds RIO_2 which are prepared by oxidizing the iodoso compounds with hypochlorite The iodoxy compounds have properties somewhat similar to the iodoso compounds

If benzene is reacted with iodine pentoxide and iodine in concentrated sulfuric acid diphenyliodonium bisulfate $(C_6H_5)_2IHSO_4$ is obtained This reaction is general for benzene derivatives and the products are typical ionic salts The iodonium salts of many common anions have been prepared as have the hydroxides which are strong bases Diphenyliodonium chloride $(C_6H_5)_2ICl$ a white solid sparingly soluble in water has found some use as a disinfectant

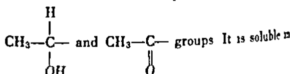
Biological importance of iodine Iodine is widely found in both plant and animal kingdoms Because it occurs in most plants in only trace concentration it has not been possible to decide whether iodine is essential to plant nutrition However in many cases additions of iodine do stimulate plant growth

Iodine is essential to higher animals because of its relation to the thyroid gland Iodine absorbed by the body is converted in the thyroid first to 3,5-diiodotyrosine and then to thyroxine both of which are iodine containing amino acids Both compounds are secreted and transported to the tissues. See BROMINE CHLORINE FLUORINE IODATE IODIDE IODOFORM PERIODATE [M F O R.E.C.R.]

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Iodoform

A yellow hexagonal solid with a penetrating odor also called *triiodomethane* CHI_3 *Its specific gravity is 4 08 and melting point 119 C It is prepared* by the action of iodine in a basic solution (NaOH) on ethanol or acetone or by the electrolysis of an alkaline I_2 KI solution in the presence of ethanol or acetone It serves as a qualitative test for the



groups It is soluble in organic solvents and insoluble in water It has weak bactericidal properties and exerts antiseptic action when applied to raw wounds because of the liberation of free iodine its chief use is in ointments for minor skin diseases It is toxic when taken internally *See* ANTIMICROBIAL AGENTS HALOGENATED HYDROCARBON [E H H]

Ion

An atom or group of atoms which by loss or gain of one or more electrons has acquired an electric charge If the ion is formed from an atom of hydrogen or an atom of a metal it is usually positively charged if the ion is formed from an atom of a nonmetal or from a group of atoms it is usually negatively charged The number of electronic charges carried by an ion is called its electrovalence The charges are denoted by superscripts which give their sign and number for example a sodium ion which carries one positive charge is denoted by Na^+ a sulfate ion which carries two negative charges by SO_4^{2-} *See* ATOMIC STRUCTURE AND SPECTRA CHEMICAL BINDING

Salts are usually composed of orderly arrangements of ions which are not free to move easily in the solid However when the salt is fused or dissolved in water the ions become free and when an electric field is applied to the salt in solution the positively charged cations move to the cathode and the negatively charged anions move to the anode At the electrode the ions lose their electric charge This process is called electrolysis See ELECTROLYSIS IONIC CRYSTAL SALT (CHEMICAL) VALENCE [T C W]

m t Catio ic pecies a e selecti ely transfer ed thr ugh th c ton ex hange membrane and ni , n c spe ies ar lecti ely t n ferred thr ugh the n n ex ha ge m mbr n to achieve th s res lt F r a d cu o of th s pa t on t ch que s e DIALYSIS

Rece tly insol ble l qu d c t o and anion ex ha ge s h e been prep red nd stud ed The i n xcha ge behavi r f the e an l g of the resins d s r b d above i remarkably similar to that of the r cro s-linked elati es. S cc ssf l application of th selecti e exch nge pr pertie fo affect g separations by solvent extraction techniques is a certa nty

Ion exclusion By this pr cess the penetration of soluble electr lyte into the re n gel phase is p e nted Th d stribution of electrolyte between tw phases in th s ase the re in and external solu ti s g en by the Don an equ librium

$$[A^{+a}]^b_{( )}[B^{-b}]_{( )} = [A^{+a}]^b_{( )}[B^{-b}]_{( )} \quad (3)$$

whe e the symbols are th ame a employed in Eq (2) This b h v or of ion excha g re ns is d ri d f om the p epond r nc f mobile i n n the gel ph e that lectr c lly n utr l z the im mobil zed charged funct n l gr up attached to the r s n

At mod at extern l ele t olyt c ntrati ns m b l i of n cha ge alre dy e s t n la ge qu ntity w th n th th t only *m nor* qua tit f elect olyte a d ff s f m the xt rnal luti n t atisfy Eq (3) At h gh electr lyt con c ntrat gn fi a t ele t olyte in a ion hould a d d es oc

Th s b ha o f e n s the b s f spec al pa ation p oces i wh h lectrol t is x l ded f m th i e ha g whil n polar *m te als* a e t F exampl lt n b s parated f m gly er n by the le t pt n of tl *nonpol* gly i [J.A.M.A.]

B bl g phy F C Na hod nd J Schub rt (ed) I E h ng T hnol gy 1956

Ion propulsion

I h cul m ti a sed by r a tio from the high peed d h g f a beam f ele t i lly qu lly ha g d m ute p rt l Th h rg d p ti l s r r el r ted n lect stat fi ld pro-d ced w th th h le that pr pell d Be u e a g n pol ty f h rg n t b ject d f om th eh cl a e t *nded* p ri d w th ut p o-du i g a b t ual ppo t pol r ty f ch g n the eh le th h c l h rg m t be m ed a part f the p op l i p oce Thu ep ate beam f po t e a d n g ti e el *ctric ch rg* e j ted a d mbi ed beh nd th v h l t el m ate l ct fi ld b v d the outl t The h ma f n cle r powe ed l t tat c p p l s o y t m h wn i F g l Th th ee *pri* p l bsyst m f th pr pul system ar th pow g er t o yst m, propella t feed sy t m nd the thru t dev e Th p we gen at sys-tem n be b ken dow i t th en gy ourc and th power-c n e s on equipment the thru t de ice into the on z r and the accel *rator*

Energy source The en rgy so rce can be a nu clear re ctor or a ol r r diation energy collector In the fir t ca e prote ti n of the electrical quip-m nt (nd of pers nnel in th ca e of manned ve-h cles) is requ r d ag i t neutr n and y rad ati n and protecti n f the ma n radiator aga n t radio-a t ity i duced in the working fluid by th reactor Effecti e neut on shielding materi ls are m tal hydrides and bo on carbide For sy tems with large electrical power outputs (megawatt range) boron carbide results in lower neutron shield weights For smaller power outputs (tens to hundreds of kilowatts) the smaller shield thickness attainable with metal hydrides contributes to greater compact ness of the power package Typical *γ radiation* shield materials are stainl s steel and tungsten the latter b ing ad antageous where high radiation i tensit es and h gh resulting operational tempera tures are in ol ed

To s mplify the pow r conver ion system it is des rable to u e the re ctor coolant as *working* fl id driving the turb ne However this is only pos-ible if the w rki g fluid is nert such a a noble *gas l ke arg n If metal* vapor is used radi acti ity is nduced by the reacto lead ng to a co tamina t o of turbi e pipel nes and radiation cooler Thi pre ding of rad oa tiv ty w uld m ke proper shield ng d ffi ult and weight onsuming Therefore two metal ycles as ind cated in Fig I are p ef *e able The fi t* cycle carries react r he t to a heat e ch ng r in wh ch the metal of a second cycle i evapo ated t d i e the turbin For th s ca e the y sh ld must be l cated n the far s de of the heat h ng r fo pr tect on from th y radi t on of *th fir t cycle metal* a well of the r act r If *only* a ingle ycle used a he t exchang n t equi d a d the y h ld ca be loc ted d ectly b h nd th n tr n shield

If the nergy so is ola *oll* ctor n ad tion sh eld i equ red d only one fl d *cycl* i r q d i a y ca e H *wever* la ge colle t r a a equ red to nt ate an adequ t *amo* nt f s l r e gy on the heat xchang r (see SOLAR ENGINE) Th di d antage f the sola n e gy so e a e the *requ r m nt of* c lle t r alig m nt w th the u dd ti n to flight *mechanical* thru t alignme t, the i b l ty to *op r t* the h dow of el *t al* body the ope ti nal r t ti n t th nner s l r sy t m and the d ffi ulty (oll t r ma nt *n e* the pre nce f unfa abl pac en m tal co d t o s (micr meteo-rites, h gh nte ty olar rad *y n*)

Energy converter The he t d v l ped gy c n e on sy tem so fa is the t b ne generator y t m On th b s of th w ki g *fluid* n d t gui hes between ga *y le a d* apo cycl O th b f th o ve on mechan m the tw *m t int* t g cycle the B ayt n ga turbine cycle and th Rank e y l Th B ayton cycl appe r m t d ntageo *for sm ll* pow pl nts (p r a few hundred th us nd l ctr n olts)

hydrates phosphoric acid groups in nucleic acid weakly acidic phenolic —OH groups and thiol —SH groups in proteins Proteins being amphoteric behave as anion exchangers in acid systems by virtue of amine —NH_2 side groups

Since 1935 organic ion exchangers have been synthesized by incorporating functional groups in natural products such as coal lignin and peat An example of this type of organic exchanger is the product from sulfonation of soft coal The sulfonic acid —SO_3H functional groups are attached to the aromatic matrix of the coal More recently cationic and anionic groups respectively have been incorporated in cellulose fabrics by phosphorylation with urea and phosphoric acid and by reaction with 2 aminoethylsulfuric acid to provide ion exchange properties

The synthetic ion exchange resins were first prepared by the reaction of polyhydric phenols with formaldehyde the weakly acidic phenolic groups providing cation exchange properties to the product Cation exchange resins containing strongly acidic sulfonic acid groups were prepared later by the condensation of phenols and formaldehydes in the presence of sodium sulfite Anion exchange resins were prepared by the polymerization of amines with formaldehyde

The most recent technique for the production of ion exchange resins consists of first forming the polymer unit followed by incorporation of the functional ionic group For example the polymerization of styrene produces linear polystyrene chains These are held together (cross linked) by divinyl benzene to produce a network structure The sulfuric acid groups are then attached to this network by sulfonating with concentrated sulfuric acid Quaternary amines may be attached to the same matrix by an analogous treatment (chloromethylation of the copolymer followed by reaction with a tertiary amine)

These resins now by far the most popular are offered commercially with various bead sizes (mesh) and with different porosity or cross linking (percentage of divinylbenzene) The degree of cross linking controls their swelling properties The low cross linked resins swell to many times their dry volume in aqueous solution while the highly cross linked resins show little volume change In the highly cross linked resin the more rigid network structure resists the sizable osmotic pressure due to the concentrated salt solution contained in the resin gel phase As a result of such constriction ion exchange occurs more slowly because of increased resistance to the movement of hydrated counter ion in the resin gel phase Differences in resin affinities between pairs of ion are also affected—increasing with increased cross linking and thereby compensating for slowing the exchange process

High porosity in an ion exchange resin results in easier accessibility to ions of high molecular weight thereby providing a basis for their effective separation from smaller ionic species

The control of resin porosity possible in this method of manufacture permits the research worker to select the most suitable tool for his specific needs In addition these resins are chemically and physically stable and possess high capacity

The functional units most often employed in synthetic cation exchange resins are sulfonic phosphonic carboxylic and phenolic groups The sulfonic resins are strongly acidic as one would expect from their normal behavior in aqueous systems The different exchange behavior of sodium ion with a carboxylic and sulfonic acid resin illustrates this acidity function Sodium ion in a neutral solution of sodium chloride will not exchange appreciably with the hydrogen ion of a carboxylic resin in the acid form since the —CO_2H groups are not appreciably dissociated Only in an alkaline system can exchange occur readily between sodium ion and hydrogen ion The continuous removal of hydrogen ion by hydroxyl ion to form water necessitates continuous replenishment of the small amounts of hydrogen ion normally replaced by sodium ion In the case of the sulfonic acid cation exchanger the —SO_3H groups are essentially completely dissociated and exchange between sodium ion and hydrogen ion can occur normally in neutral systems

The functional groups for the synthetic anion exchange resins are usually amine When primary secondary and tertiary amine are incorporated the exchanger is weakly basic since the amines are strongly associated in aqueous system If the functional group is a quaternary amine the exchanger behaves like a strong base

The incorporation of other functional groups to produce unusually selective ion exchange resins has been attempted with some success For example thiol —SH groups have been used to provide a resin which exhibits a special affinity for metals that form mercaptan incorporation of a chelator group *m* phenylene diglycine produces a resin with a high selectivity for the transition elements

The presence of immobilized functional groups and the neutralization of their charge by mobile ion of opposite polarity provide the resin with preponderance of mobile ions of one charge For in the presence of moderately concentrated electrolyte solution electrolyte diffusion (in a ion) into the resin gel phase does not alter this situation As a result there is selective transfer of the mobile counter ion under the influence of an electrical potential gradient Ion exchange membrane coherent sheets of ion exchange resin have been prepared to take advantage of this characteristic property *S* ION PERMEABLE MEMBRANE

A principal application of ion exchange membrane has been the development and improvement of electrodialysis technique for separation For example by arranging cation and anion exchange membrane in an alternating pattern between electrodes the imposition of a potential gradient will result in the concentration and dilution of electrolyte contained in the [illegible] boring compar

le a d s t m Th the mal p wer tput f tl e ctor m t the ef e b 4–16 time l rge than the kw o tput. Th ne gy d fferen e m t b r d ted t pac F tl e g s cycle the ad at r are equ r d is at lea t 9–10 ft²/ekw at 1300 1400 F r d t r nlet temp r t e whil fo mer c ry and s d m the al e are 3–4 ft /ekw for 1300–1400 F 1 ft /ekw f 2000 F a d 0 8 ft /ekw f r 2300 F Depend ng n the qu r ments f r r diato d n t mp t e (t l ab e 1000 F t tan m 450–1000 F l m m bel w 450 F) and m c om t or pr tect n th ad at r we ght will ary greatly An al m um d on with t b du t n the wo king flu d w ll we gh a und 1 5 lb/ft the r b s be n prot ted by bumpe (ute hell) again t microm t rite p t at n Al m n m d at s fo g ycl we h 0.5– 0 lb ft w th mete r bump r F te l th cor e p nd ng al ies a 1 1 1 5 ll ft fo tube fl id arra em ts ga y l ad t r respe t el F r e y lar e ad at r of 10 000– 0 000 ft a we ght of 4–5 lb ft nclud ng l g term m r m te r p ot ct n by b mper m t be e pect d Th rad to r p es t th h a t nd l t rta mp e t f the pr p l on y t m

Alte nate p we n e s on sy tem re the m d t r a d the therm on c d od Sem o d c t (tl rm ples) pr d d r ct on er n of h at t l tr ty (e THERM COUPL) P nt sy tem ha e an ffecie cy f 5–6% impo ng a g eat burde on the heat rejecting radiator It i hoped w th f ture l igl temp rat r tl erm ouple to reacl an efficien y f 10 13% I the th rmi nic d ode el ctron are l led ff a h t plate and are nden ed n a cold plat (see THERMOELECTRIC ITY) C ium ap r i t red between tl e plate t n utral ze pac charge and to adj t tl e work functi n f tl e l ctr de Th rmi nic t m f m t ial for h gh t mp rat re perati n can be develop d c n att in ceptable ff c nc at h gh rad ator t mperature (mall radiator area) a h wn in F g 4 Be a of th cha a t ri tic and be a f tl e al ence of large r tat ng eq ip- ment tl e the mi ni c n erter the mo t att ac t e co e i n y tem of th future (Fig 5)

Propellant Th i ize r i n urce con rts tl e propellant f om it rig nal tored f rm t a sy tem of ch rged c pu le The e c n l e e ther atoms each depr d f n el ctron (p iti i n) r sm ll liqu d dr plet or l d particle t which negat e charge (le t n) s attached Tl cha ged hea y pa ticle th t are llecti ly r fe red t as ll id r q re l igher voltag f r the sam a ele at n o at th ame ac el rati g It g y eld l e e h t l ity Pr m ng meth d of ion zati a the cesium urfa e n zat n p po l for n p op il n y tem l y E Stul l 1954 and th n Ardenn g l matr n i ce

I the urf ce on zati n sy tem e um vapor i impi g d n l t platinum r t ng ten g d The i n zat n p tenti l f c ium (3 87 lt) i le s than the oltag r q i ed t rem a el ctr n f om the gr d rf e (w rk fu ct n f the plati num ti ten) Th imp ged m at m e p ate that esi m vap mp nge on the hot gr d d re por t i ngly i iz d form ha ng l t e l t n f e h i Th l l ng temper ture l m i 1130 F The g d tem p at r mu t be p op ly adju ted If it i too l w n t e u h cesium e ap at s w th r lant for m tion of a c at whi h redu s the ion zat n effi c of th g id If th temperature i to high ele t on es ap f om th s f t g ther with the io r d i g the numb r of ns ent r g th a

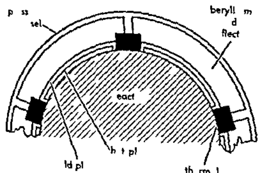


Fig 4 Effi cy f l ct l c y t ms f ct f op o l d d to l t t mp d h d l P i cted l

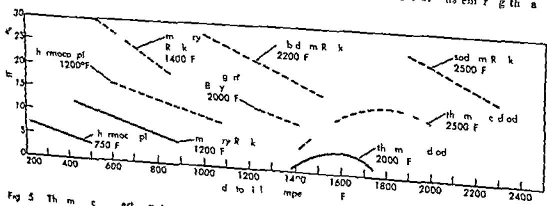


Fig 5 Th m c ert sy t m

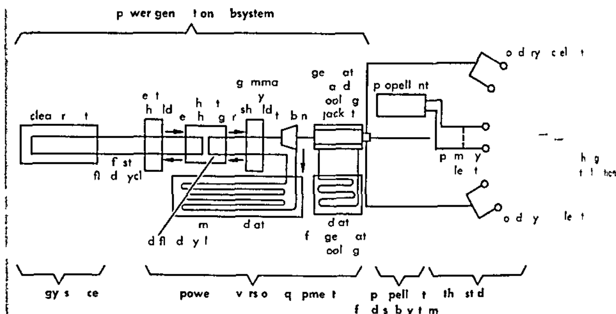


Fig 1 Schematic presentation of nuclear powered electrostatic propulsion system

using a gas cycle the preferred fluid being argon a heavy inert gas A typical Brayton gas cycle system is shown in Fig 2 Heat is transferred from the reactor to high pressure gas the gas is then expanded in a turbine which drives a generator and compressor Upon leaving the turbine the gas is cooled in a radiator then recompressed and fed back into the reactor (*see* BRAYTON CYCLE) In the Rankine cycle a liquid is used for heat transfer from the reactor leading to evaporation with subsequent expansion of the vapor in the turbine the direct Rankine cycle (*see* RANKINE CYCLE) Because this would spread radioactivity the indirect Rankine cycle provides for a heat exchanger between a primary all liquid cycle and a secondary liquid vapor cycle Because of uncertainties in the boiling heat transfer rate under weightless conditions in space the intermediate link Rankine cycle of Fig 3 appears most attractive Separation does not occur in the heat exchanger but in a boiler separator The saturated liquid from the heat exchanger is expanded to high velocity in the boiler separator A portion of the liquid evaporates In subsequent spiral ducting liquid and vapor are separated by centrifugal effect The vapor is ducted to the turbine and the liquid is returned to the heat exchanger together with liquid from the radiator in which the vapor is condensed and cooled following expansion in the turbine Suitable working fluids are mercury for smaller power plants and sodium or rubidium for larger systems

The radiator is the largest and heaviest component of the power generation system Its purpose is to radiate excess heat into space This heat is the result of limited efficiency of energy conversion The efficiency of the conversion system defined as ratio of electrical power output (ekw) to thermal

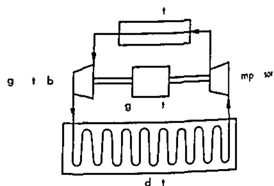


Fig 2 Power generation system using the Brayton gas cycle

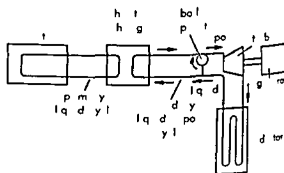


Fig 3 Power generation system using the intermediate link Rankine vapor cycle

power output (kw) of the reactor is 6–7% for 3-ekw system (mercury Rankine cycle) about 13 for systems in the 30 300 ekw range (mercury Rankine cycle or argon Brayton cycle) and 20 23 for 1 000 20 000 kw systems using rubidium or sodium Figure 4 shows a survey of the achieved and expected conversion efficiencies for various

cult Fort nately the field of an i n beam ext acts le tron of ne by h t fil ments the eby k ep ng h v hicle ne tral and pr ding the electro s needed for pa e-ch rge eut al zation The general arr ng me t of th lect o sou es and the o cil lating p th through the low-den it i n beam under th combin d eff ct f th ir wn th rmal elocity (wh h is compa able t the elocity f the ons 100 000–300 000 ft/ ec) and the attracting electr c field f th o beam ar shown i Fig 6

Low io mass s h gh ltage nd sh rt accelera ti n chamb rs a e requ ed for high current den ties. O the other hand for a g ven exhaust eloc ty (r specific imp l e) high thrust d n ity requ res l rg ion ma s E pec ally f r lowe spec fi im pul es emph s on heavy i ns if a low thrust de sity i to h avo d d

The spec fi impul e c nnot s mply be elected to be a max mum but m st b optimiz d as a function of propul ion t m propul n y tem w ight, and effi ie cy of co ert ng ele tr cal powe into power of the exh ust j t. F r mi s on to the moon p c fi impul e of 3000–7000 sec are equ ed for m t Ve us or Ma s spec fic impul es of 10 000–20 000 sec a needed Spec fic imp lse be yo d 20 000 sec are f i t re t nly for mi io s to the borde s of our ol r ystem *See* ELECTROSTAC NETIC PROPULSION MAGNETOGAS DYNAMICS NU CLEAR AIRCRAFT PROPULSIO e al o INTERPLA E TARY PROPULSION [K.A E.]

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Ionic crystals

A cl f cry tal wh h th l tt e t oc p nts a I rged i n h ld t g th p ma ly by the l i tat int r t Su h b d g s alled n c bi d g Fmp ll c tals d i g h d by i g ab pti n f i f r d r d i on g od n c c nd ti ty at h gh t mpe a t res l th x ten of pl es l g wh h th y tal l a ily

Comp nd f t ngly l tr po ti a d t gly l t o g t e el ment typ cally form sol d wh h a y t l fo ex mple th lk l h l d th r m l nt m tal h l des a d the lkal e rth h l de xides nd ul fid Cry t l i wh h some of th n r com pl x h a m t l a bo ates m tal tr tes d ammonium salt may al be cl sed as io ic crys tal

As a cryst l type i nic cry tals are t be dis tingui hed from ther types uch as molecu lar crystals alence crystal or metals The ideal ionic cry tal a defined i appr ached mo t clo ely by th alkali hal des Other cry t ls ften cla sed as i n c ha e bindi g wh ch is n t exclu ively i nic but includes a certa n admixture of cov lent b nd ng (see CHEMICAL BINDI G) Th s the term i nic cry tal refer to an ideal zation to which real crys tal correspond to a greater or les er degree and cry t ls e ist ha ing characteristics of more than one crystal type

Because of the relative implicity of ionic crys t ls especially the alkali halide the r thermal m chan c l opt c l and electric l properties ha e b en the subject of much experimental and theo retical n est gation

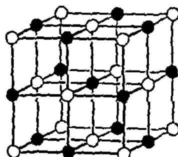


Fig 1 Sod m hl d latt Bl k d t p sent p tive s (Aft F S i Th M de The ry of S l d M G w H ll 1940)

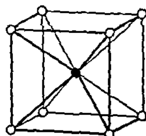


Fig 2 Ce um chl id l tt (Aft F S itz Th M d Th ry f S l d McG w H ll 1940)

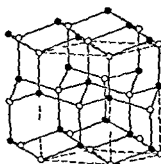


Fig 3 W rt t l tt (Aft F S tz Th Mod Th ry f S lid M G aw H ll 1940)

celerating electrostatic field. In view of the fairly high boiling temperature a high grid temperature (2200 F) is required. To avoid undue power losses by radiation over long propulsion periods a proper geometric arrangement of the grid elements is necessary. In the acceleration chamber the (positive) ions are accelerated toward the cathode (Fig. 6).

The von Ardenne plasmatron ion source uses electric discharge to produce a neutral plasma. A strong magnetic field is employed to generate high plasma density, thereby increasing the degree of ionization (Fig. 7). In the charged colloid system the fine droplets or dust particles must be produced first, then must be ionized. The various possibilities of producing colloids and accomplishing the ionization efficiently are not yet fully explored. *See* AEROSOL; COLLOIDS; *also* SMOKE.

The space charge represents one of the major obstacles of any ion-propulsion system. By ejecting a singly charged beam, repulsion forces tend to diverge the beam. Therefore high current density calls for fast beam acceleration at high voltage in a short accelerator. The Rocketdyne Division of North American Aviation reported current densities of ~20 ma/cm² with cesium, 6000-volt acceleration and an accelerator length varying from 3 mm to a fraction of 1 mm. Although space charge limits ion beams to a density in the order of 10[illegible]–10^{11} ions/mm³, space charge effects require rapid neutralization of the beam after it has left the propulsion system. Continuous ejection of one charge would gradually charge the vehicle in the opposite direction and high speed ejection of the ions in r[illegible]

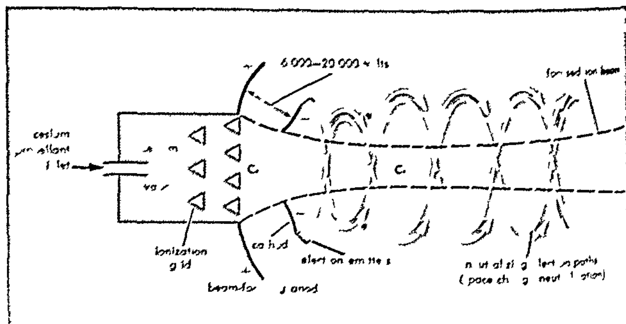


Fig. 6 Cesium ion thrust device

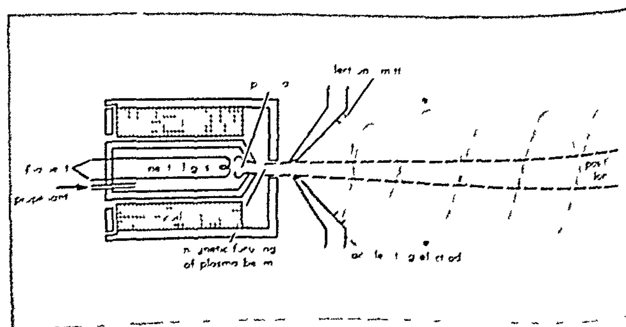


Fig. 7 Plasmatron ion thrust device

cult F rtu ately th field f an ion beam tracts lectrons f n arby h t filaments thereby keeping th eh cl neutral and pro d ng tl e electron needed for pa e-cha ge n ut alizati n The g neral arr gement f th el ctron s u c a d tl ir o il l t ng p th through the low den ty on beam under the c mb ed effect of tl e r own thermal v l ity (wh h is mparabl t the el c ty of the ion 100 000–300 000 ft/ ec) nd the attr ct ng electric field of the i n be m are hown in Fig 6

Low i n mas es high voltag and hort ccelera ti n chamb rs are required for high current den i ties On the other h nd fo g en exhaust elocity (or specifi mpuls) h gh thru t density requires la ge i n m s Especially for low r specific im pulses emph si is n heavy i ns if a l w thrust d ity is to be a ided

Th specific mpul e cannot mply be el cted t e a maximum but mu t b opt mi ed a a fun tion f p opulsion t me, pr pul on sy tem we ght and ffi ie cy of on ertu g el ctri al p we into p wer f th exhaust jet. For mis ns to the moo spe- ific mp l s of 3000–7000 e are requi ed f r n ions t Ven s o Mars, specific impulses f 10 000–20 000 ec r needed Sp c fic impuls s be- y d 0 000 sec a e of nte e t nly f r m s i ns t th borders of our s lar sy tem *See* ELECTROMAG- ETIC PROPULSION MAGNETOGAS DYNAMICS NU CLEAR AIRCRAFT PROPULSIO s l o INTERPLA E T RY PROPULSION [K A E]

B bl gr phy R H Bod n *The Io Rocket F gi e* R cketdyne Rept. R-645 1957 K A Ehricke *I P op l Sy t m O b tal S ab li z t of S tell t s F p c ally of Set l Sa ll t Cl s ly S mil O bits* Con ai Ast naut c R pt. ASM 2 pt 1 1957 H S Seifert (ed) *Sp T hnology* 1959 F Stuhl ng De n and p rf rman dat f spa sh p with ic p pul ystem *P c d g f the E ghth I t na n l A t t c l C ng s* 19 8 E Stuhling r nd R Se tz, Some p oblem i n p p l n y t ms *IRE T ns Milu y El ct on cs* MIL-3 ( ) 2 33 1959 M A d ne N w Dei lop *m t n Appl d Io d N l a Physic* At m c F e gy Res h E t bl Tr s 758 1957

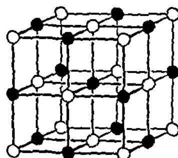
Ionic crystals

A l s f) tals in wh l the l ttı e s t o u p l a h g d o held t g ther p m ly by th el t t l nte ti n Such b nd g lled n b nd g Emp ll n ry t l a d t gu h d by t ng ab pt f nf a d d t good i d t ty t h gh t mp r t es d th i te c f pl als g wh h th y tal l e ly

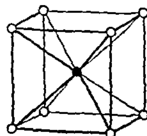
Compo d f t o gl l t op t v a d t o gly elect n gat elem t typi ally f rm sol d h h a e c y t l f ex mpl th alkal h l d th m o l nt met l h l de a d th alk l e rth h l d x des nd ul fid Cry t l i wh h some f th ar m pl h m t l bo at m tal n t t d ammon um alts may al o be cla d as i nic cry t l

As a crystal type i ni crystals are to be dis- tinguished from other types ch as m lecular crystal lenc cry tal or metals The ideal ion c crystal a defined i appr ached m t clo ely by th alk l hal des Other cry tal often cla ed as ionic ha e bind ng wh ch i n t exclu i ely i n c but includes a certain adm xture of co alent bind ing (s e CHEMICAL BI DING) Thus the term ionic cry tal refers to an idealizat on to which real crys- tals corr pond t a greater or les er degree and ry tals exi t having characteri tics of more than o e crystal type

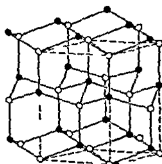
Becau e of the relati e simplic ty of ionic crys- t l espec ally the alkali hal des their thermal mechan al optical and electrical pr perties ha e be n the subject f much experimental and theo- retical in e t g tion



Fg 1 Sod m hl d l tt Bl ck dots r p e t po tiv (Aft F S t Th M d Th y f S l d M G w H ll 1940)



Fg 2 C m hl d l tt (Aft F Se t Th M d Th ry f Sol d M G w H ll 1940)

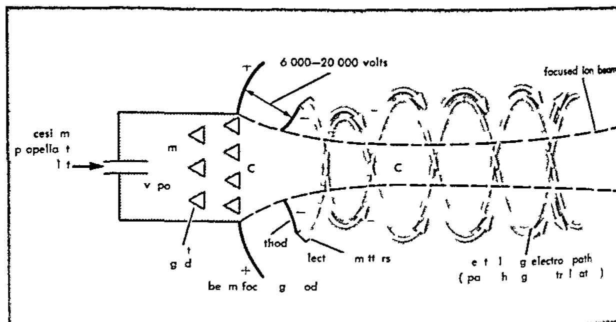


Fg 3 W rt t l n (Aft F S itz Th M d Th ry f S l d McG w-H ll 1940)

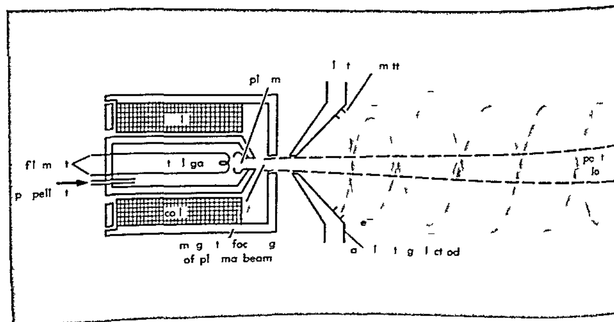
celerating electrostatic field In view of the fairly high boiling temperature a high grid temperature (2200 F) is required To avoid ur due power los es by radiation over long propul ion periods a proper geometric arrangement of the grid elements is nec e sary In the acceleration chamber the (positive) ions are accelerated toward the cathode (Fig 6)

The von Ardenne pla matron ion source uses electric discharge to produce a neutral plasma A strong magnetic field is employed to generate high plasma density thereby increasing the degree of ionization (Fig 7) In the charged colloid system the fine droplets or dust particles must be produced fir t then must be ionized The various possibilities of producing colloids and accomplishing the ioni zation effectively are not yet fully explored *See* AEROSOL COLLOID *see also* SMOKE

The space charge represents one of the ser obstacles of any ion propulsion sy tem By prod ing a singly charged beam repulsive Coulo forces tend to diverge the beam Therefore, h current density calls for fast beam accelera high voltage in a short accelerator The Rock dyne Division of North American Aviation has r ported current densities of 3-20 ma/mm w cesium 6000-volt acceleration and an accelera length varying from 3 mm to a fraction of 1 m Although space charge limits ion beams to a d sity in the order of 10^{9}–10^{1} ions/mm spa charge effects require rapid neutralization of t beam after it has left the propul ion system. Co tinuous ejection of one charge would grad charge the vehicle in the opposite direction, mak high speed ejection of the ions increa ingly d



Fg 6 C um o thrust de e



Fg 7 Pla mat on i n thr t de c

he f ll w g nume ati n f th tep n the Born Hab r y l (A) nd ate l me t A i a mo a m g eou t te d $[A]$ indic t s A in lid tate d The B with t br k t i step (3) r fer to th n tu al f rm of B at th g en mp ature nd p essu e The io i mp u d i ken t b AB wh A i the el t opo ti e d B the el tr neg t e elem nt

Th tep f th B rn Habe Cycle (ll tempe a tures n K and p s res n tmo ph re)

1 $[AB]^{0}_{P} \rightarrow [AB]^{0}_{P=1}$ The al f ΔH_1 in th s th rm l mp n i ry mall and can be n l ct d c mp r n w th oth r he t c nt nt ha es in the ycl

2 $[AB]^{0}_{P=} \rightarrow [AB]^{298}_{P=1}$ In th step the crystal i rmed t oom temper t r The al e of ΔH can be l l ted f m th spe ific h at t c nstant p es f th rystal

3 $[AB]^{0} \rightarrow [A]^{298}_{P=1} + B^{298}_{P=1}$ The v l e of ΔH gi n by th h t f f m t n of the c m po d AB h ch ef r ed to s bst nces n the n t r l f rm t tand d temper tu e and p essu *Se* THERMOCHEMI TRY

4 $B^{298}_{P=1} \rightarrow (B)^{298}_{P}$ The l e f ΔH the d t n n rgy c s y to f rm m n tom c gas f m B ts t l stat t standard tempe t nd p ess re F chlo des f e ampl th s s th d s at n n gy f Cl_2 mol ul to Cl t m

5 $[A]^{298}_{1} \rightarrow (A)^{298}_{P}$ I th s t p ΔH_5 s the h t f bl m t n of th metal A It n be ded ced f m th he t f f i the pe fic h t f th s l d, l q d nd gas phas s nd th po p es d ta f r th m tal *See* SUBLIMATIO

6 $(A)^{298}_{P} \rightarrow (A)^{0}_{P}$ $(B)^{298} \rightarrow (B)^{0}_{P=}$ An d abatic pan n f th ga ns d ed as deal t ry l g l m res lts n a stat wh h $P = 0$ $T = 0$ and $\Delta H = -5/2 RT$/m le wh R th g tant

$(A)^{0}_{P} \rightarrow (A \;)^{0}_{P} + \;^{-}$ The nizati n of the A at m gi s ΔH pe t m pu l t their first zat y

8 $(B)^{0}_{-} + \quad \rightarrow (B^{-})^{0}$ Th l ctr ns fr m tep (7) a pl ced the B toms Th alu of ΔH pe at m gi n by the el t n affin ty f th B t m (see ELECTRO EG TIVITY)

As ample fo sod um hlo d $\Delta H \cong 10^{-4}$ (k local ries/m l) $\Delta H = 2.4$ $\Delta H = 98.3$ $\Delta H = 60$ $\Delta H = 88$ $\Delta H = -29$ $\Delta H = 119$ and $\Delta H = -80.5$ Experim tal c hes rgies for n mbe f the n ry t l ar gi n i the mpa y g tabl *See* CHEM CAL STRUCTURES

B *May* *q* *t* By e f the B rn Made l g mod l the c h e gy f a i n c cry t l n be l ted t t m ed mp ib lity a d

Cohesive en rgies

Cry t l	Stru t re	U_{exp} kcal/mol	U_{calc} kcal/m l	U_{cal} fi ed kcal/m l
L Cl	N Cl	01	196 3	00
LiB	N Cl	191 5	181 4	189 5
LiI	N Cl	180 0	169 1	1 61
N Cl	N Cl	181 7	18 0	183 5
N B	N Cl	1 59	I	1 5 5
N I	N Cl	166 3	159 3	161 3
KCl	N Cl	16 8	165	167 9
KB	N Cl	161	158 3	161 3
KI	N Cl	15 8	148	15 4
RbCl	N Cl	163 6	1 9 1	16 0
RbB	N Cl	159 0	1 1 9	156 1
RbI	N Cl	149 7	143 1	148 0
C F	Fl orit	618 0	617 7	
C Cl	Z bl d	6 3	06 1	
Z S	W tz t	8 1	816	
PbO	R tul	831	6 0	
AgCl	N Cl	07 3	187 3	

Th cohes gies th l t tw col m re cal cul ted us g th Bo M y eq t d th ref nd Bo M y theo y espect ly Th f d l l t f th l t fi y tals med h t bee m d

lattic pa g B ca e of the opposite signs of elect c h rg which they carry the unl k i n i s ch a cry t l m del att act one an ther acc rd i g to Co lombs law Howe er ch a charge d t b tio nn t be n qu librium if ly Cou l mb f ce ct I addit o t th ir Coul mb nt ra ti the i exh bit a repul on wh ch ompa ed w th the Coulomb inter t aries ap dly w th inte io i epa at n The repuls on be m st ng f r small separations and dimi he r i dly fo i rea ng eparat on The st t c quil br m c nfigu ati n of the cry tal d ter m ned by a bal n e f these f rc of ttr tion nd p l o

Th h rt a ge rep l on betw n ns m t be des bed by q a t m mech nic Wh n the el c t n b t f two n lap the l ctr harge de ty th g n f erlap i dim nished a a c seq ce of the P uli e clu on p in ple Th ch rg ed t b t n re lt in pul i between th i n in add t t th Coul mb inte t on which they ha e at all ter oni di t nce I a ly wo k th e gy V due to pul o of two s t a di t e r w ssum d t ha e th f m

$$V_{re} = B/$$

whe e B nd n a e tants to be d te m d Qu t m m h l l latio s f th inte ac t o of at m w th l ed shell f l t nd ate that th t cti n f r pulsi n s bette pp m t d by an exp ne t l dep dence n nt c d t e

$$V_{re} \quad A \quad /$$

wh A a d ρ a c st nts B th f rm f l g almo t the am l l ted he i e en gy th p ti l f m g s sl ghtly b tt g m t with p m t

Crystal structure The simplest ionic crystal structures are those of the alkali halides At stand ard temperature and pre sure the 16 salts of Li Na K and Rb with F Cl Br and I have the sodium chloride structure of interpenetrating face centered cubic lattices (Fig 1) C F al o has this structure but otherwise the cesium halides have the cesium chloride tructure of interpene trating simple cubic lattices (Fig 2) The sodium chloride structure is al o assumed by the alkaline earth oxides sulfides and elenides other than tho e of Be and by AgF AgCl and AgBr Other cry tal structures such as the wurtzite structure (Fig 3) a sumed by BeO β ZnS and ZnO and the zinc blende structure (Fig 4) assumed by CuCl CuBr CuI BeS and α ZnS are also typical of the ionic crystals of salts in which the atoms have equal positive and negative valence Ionic compounds con i ting of monovalent with divalent element cry tallize typically in the fluorite structure (Fig 5) assumed by CaF BaF CdF_2 Li_2O Li_2S Na S Cu S and Cu_2Se or the rutile struc ture (Fig 6) assumed by TiO ZnF and MgF *See* CRYSTAL STRUCTURE

Cohesive energy It is po sible to understand many of the properties of ionic crystals on the basis of a imple model originally proposed by M Born and E Madelung In the imple t form of thi model the lattice site are occupied by spherically symmetric ions having charges corre sponding to their normal chemical valence The e ions overlap only slightly the ions at neighboring

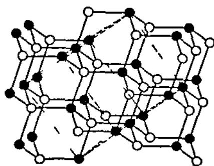


Fig 4 Z c bl nde latt ce (Aft F S t The Mod n The ry f S lds McG w H ll 1940)

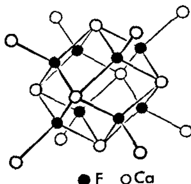


Fig 5 C lcum flu r de l tt c (Aft F Se t Th Mode n Theo y f S ld M G w H ll 1940)

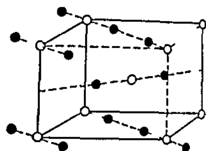


Fig 6 Rut le latt ce (After F Se tz The Mod Theory of Sol ds McGraw H ll 1940)

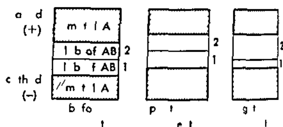


Fig 7 E pe ime tal arrangeme t fo m as r g o conduct vity

ites and interact with one another through cen tral forces In NaCl for example the pherically symmetric closed hell configuration which the free Na and Cl ions possess are con idered to be negligibly altered by the cry talline environment and to have charges $+e$ and $-e$ re pectively where $-e$ is the charge on the electron Using this model together with certain as umptions about the forces between the ions Born and M G ppert Mayer calculated the cohe ive energy of a number of ionic crystals This coh sive energy is d fined as the energy nece sary to take an ionic cry tal from an initial state in which the crystal is at 0 K and zero pre sure to a final state which i an infinitely dilute gas of its con tituent ions at 0 K and zero pressure *See* COHESION (PHYSICS) Wh le it cannot be m asured directly thi cohesi e energy can be deduced from experimental quantities by the use of the Born Haber cycle Thus the validity of the imple model of Born and Madelung can be tested by comparing the calculated cohe ive energ of Born and Mayer with the experimentally deter mined values

Born Haber cycle This is a equence of proce es leading from the initial to the final state pecified in the definition of the cohe ive energy Because in most of the proces es in this cycle heat chang at con tant p essure are mea ured it is convenient to consider the change in heat content or enthalpy $H = U + PV$ where P is the pressure V is the volume and U i the cohesive energy rather than the change in E in each tep Since the total change in H is independent of the intermediate steps taken to accompli h it the ΔH for the change in tate spe ified n the definiti n of cohesive energy will be gi en by the um of the ΔH in the steps of the cycle Furthermo e because when $P = 0$ $\Delta H = \Delta U$ the ΔH thus calculated will be the c he ive energy In

v of elect oly rel t ng the charge t an p rt d th matt tran port i hown t b ald If e r nt w re c d by free elect n this uld not be the c s

In mber of i n c cry tal t ha b n e tab- h d wh h f the on a e re pons ble f r th nd cti a d h w they move In a c y tal f th pe A B an e perim t t determ ne the r l t v ontribut of A and B i s t the io i c n u ti ty i d ne i the foll wi g ma ner (e ig 7)

Two lab 1 nd 2 of the cry t l A B ar e ed tog th r b tw en ele t de of m tal A d a current i pa d th ugh them. If the posi o al ca r ed th rre t th c thode ro ld n r a n we ght a d the anod w uld de- a but th lab w ld ema n uncha ged i ff on if othe f nd n gat i ns al ne a r d the cu nt the e i ns would b omb ned v th th m tal f th n de to n e e the th ck ies f lab 1 wh le em l f negati i n f om th g on f th ath de ould c u e t to in r a t we ght th po t on of the bo nd y b tw en 1 nd t mo i g In g neral the ca w ll be n t m d te b tw e th e extr mes By weigh ng the l ct d nd the slab b f e a d ft r p s- ing cur t can n pri pl d t rm n the fr c ti n f th ent arr d by th po it e nd n g t on These fr t n wh ch a e lled the tra sp rt umber f the on d ffer for d ffe e t cry t ls

I i o d t ty eq i th moti n f i n the latt and th i ncern d with d part re f m the d l ry tal de c ib d thus f r I the m l eq l b m at temp r t es bo e 0 K the e lway po t nd gati i n a an e nd nt r t t l i n p e e t A ac cy form d by re- m g a latt ce- ite c pa t t th u fa e f th ry t l i a g b h nd a v a cy ll d a Sch ttky def t If the a n v f m d by em g n i to n i t t t l p t n fa f m th a y th a y nte t t l p s call d F k l defe t The mb r f e h f th e d fect p nt d pe d on the tempe t re the f rm t gy f th d f t th n mb r f t t ti l tes a d c n de t s f l ctr c l neut l t R th th d t ance h ng f on th d l crv t l t the m t n f the a an a d th t t ti l i ns r both that s pon bl f n ondu ti t The mech n sm esp s ble f r i n o du ti ty al t pon bl f elf-d ffu (s th ry t l nd t d f th tw ph nomena ha h lp d t la f th mecha ms f n migrat n (Dif r si v t i ns) E pe me ts h sho n that i lkal l d S h ttky defe ts p ed mi t nd th t n c nd ti ity oc u h ffy th o gh p si t n y m g ati n f the l h l le on th th h d F kel defe t pred m n t nd p t i n ter t t l m gr t n by th nt f t l y m h n m th m t ign fic t p e s l ed

Ionic c nductivity is only one of many p r pertie of ionic crystals which depend critically on the d f cts in the cry tal Se CRYSTAL DEFECTS

Dielectric properties The p larization of an on c cry tal in an pplied time arying electric fi ld depends n the f equency of the fi ld If = 0 the fi ld i t t c and a tat c equ librium will be achieved in wh ch th i ns are d place l fr m the r latt ce ite d tance determin d b a balance betwe n the f rce of repul on d e t their ne e t n ighb rs a d the electrical f rc on th i ns Opp t ly cha g d ions move in pp ite d ect o s with a re ult n ion c p larization In addit n th el ctr n cloud of th ion are de f rmed i the local electri field at th ions a d to a much le r ext nt by the repul i e forces t gi e an le t oni polar zation As the frequency ν increas ine tial ffects m t l co d red When s ffici ntly h gh that i when $\nu >$ (i the n tu al f equ nc of v br tion of ion about lattice te) th he v i n ca no l nger f llow the r p d v riat ons f the appl ed field The o ic p larization cea e to c nt ibute to the t tal pol ri zat on although th le s mas ve ele tr n cl ud co tinu t gi n lect on c pola zat n Eve tu lly with inc ea ing fr q ency ex eeds th f eq ency at h ch the ele tr n cl ud d forma tion can follow th field and the el tr nic p la i zat n be me altered The freq ency ν_0 called the restrahlu g r e du l y f eq iency lies in the nf r d eg n nd the iat d br ti n of the charged o s a e e pon ible fo th st ng b pt o of nf a ed r diat on in i ni cry tals The term re d al ay f eq en y c mes fr m the fa t th t th reflect ity of is ble and inf ared ad ation is h h t f r rad at on f frequen y ea to th t of max mum al o pt n Thu mult ple efl ti n w ll y ld r di t on c mp sed p ed mi antl of e d al ys of f equen y ne to For add ti nal inform t on o re dual rays s e RE LECTIO (ELECTROMAGNETIC RADIATION)

Ionic radii It h s been f nd that n radi a be h se ch that th latt c pac ng of o ic ry t ls r gi en appr imat ly by the s m of th r d i of th on t t nt ion Thus f n t nc 8 rad i s ffi e t g e th app ox m t latt c p c i g f the 16 alk li h l d s ha i g sod um chl de t ctu Th s is tru b u e of the p d aria t on of th repuls ve nt ct n with d tan e so th t the i s i t ra t som what l ke f d ph es Th e i the impl at n that a g en ha g th me i nic radiu in a a iety of ry tal ha n lect n clo d wh h s only sl ghtly ft d by the d ff ng ry tall n om t f th rys- tals S ral tabl s of io adi appea in th r f ere ces gi en i the bibl ogr phy [B C D]

B bl og aphy M B rn and K. H ang *Dy n m l Theo y f C yst l Lattic* 1954 C. K t t l I t d ct n to S l d Sta Phy cs 2d ed 19 6 L. C. Paul g *Th N tu e f the Chem al Bond* 1939 F Se tz *Th M d n Th y of Sol d* 1940

Using the exponential form for the repulsive interaction energy the potential energy $\varphi(r_{ij})$ of a pair of ions i and j can be written

$$\varphi(r_{ij}) = \frac{Z_i Z_j e^2}{r_{ij}} + Ae^{-r_{ij}/\rho}$$

where Z_ie and Z_je are the net charges of the ions i and j and r_{ij} is the distance of separation of their centers. The assumption that the ions are spherically symmetric has been used here in writing the Coulomb interaction as that of point charges.

The cohesive energy U of an ionic crystal due to the Coulomb and repulsive interaction of its ions is the sum taken over all pairs of ions in the crystal

$$U = \frac{1}{2}\sum_{ij}{}' \varphi(r_{ij})$$

where in the summation the lattice site indices i and j range over all sites of the crystal. The prime on the summation sign indicates the exclusion from the sum of terms for which $i = j$ and the factor of ½ avoids counting pairs of ions twice.

For crystals in which there are only two types of ion the Coulomb or electrostatic part of U, U_C, can be written in a simple form

$$U_C = \frac{1}{2}\sum_{ij}{}' \frac{Z_i Z_j e^2}{r_{ij}} = -\frac{N\alpha_M(Z_+Z_-)e^2}{r}$$

where $+Z_+e$ and $-Z_-e$ are the charges of the positive and negative ions, N is the number of ion pairs in the crystal, r is the nearest anion-cation separation, and α_M is the Madelung constant. See MADELUNG CONSTANT.

By anticipating that ρ will be small compared to the nearest neighbor separation, the interactions of repulsion may be neglected for pairs of ions other than nearest neighbors. The energy of the crystal model for arbitrary nearest neighbor separation r is then

$$U(r) = N[-\alpha_M Z_+ Z_- e^2/r + MAe^{-r/\rho}]$$

where M is the number of nearest neighbors which each ion has in the crystal.

The parameter ρ may be evaluated for a given crystal by requiring that (1) U be a minimum for the observed value of r and (2) that the compressibility of the model equal the measured compressibility of the crystal. It follows from these requirements that

$$U(r_0) = N\alpha_M Z_+ Z_- (1 - \rho/r_0)\, e^2/r_0$$

This is the Born-Mayer equation for the cohesive energy where r_0 refers to the nearest neighbor distance at static equilibrium. Further, in this equation ρ is given in terms of experimental quantities by

$$\frac{r_0}{\rho} = \frac{18r_0^4}{\alpha_M e^2 K} + 2$$

where K is the measured compressibility of the crystal.

Cohesive energies for some alkali halides and crystals of other structures calculated in this way are shown in the accompanying table, where they can be compared with the experimental values for the cohesive energy. The agreement is considered to be support for the essential validity of the Born-Mayer model. The model has been applied with some success even to the ammonium halides assuming spherically symmetric ions.

The Born-Mayer theory has been refined with resulting improvement in the agreement between the calculated and experimental cohesive energies for alkali halides. The refinements have considered the small (a few kilocalories per mole or less) corrections to the cohesive energy arising from Van der Waals interactions and zero-point vibrational energy. The Van der Waals forces are weak attractive forces between ions due to mutually induced fluctuating dipoles. Similar forces, even weaker, due to dipole-quadrupole interactions have also been considered. Both these interactions make small positive contributions to the cohesive energy. At 0 K the lattice is not in static equilibrium but, as a consequence of quantum mechanics, is in a state of zero-point vibration with non-zero energy. The energy of these vibrational modes can not be further reduced. The zero-point vibration energy gives a small negative contribution to the cohesive energy. The results of these refinements are also shown in the table. See LATTICE VIBRATIONS.

While it has had success in calculating the cohesive energy, the shortcomings of this simple model become evident in its failure to predict correctly the elastic shear constants of ionic crystals. This requires interionic forces of a noncentral character which are absent from the model. There are also other instances in which the simple model is found to be inadequate.

Ionic conductivity. Just below their melting point, ionic crystals have conductivities of the order of 10 (ohm cm). Below the melting point the conductivity falls rapidly with decreasing temperature. In a temperature range sufficiently near the melting point the temperature dependence of the conductivity σ is exponential and of the form $\sigma = ce^{-\phi/kT}$ where c and ϕ are constants. In this so-called intrinsic range the conductivity is characteristic of the material and relatively unaffected by small concentrations of impurities and the previous thermal history of the crystal. At lower temperatures σ departs from the exponential behavior of the intrinsic region in a manner which does depend on impurities and history. For positive divalent impurities in alkali halides these departures have been extensively studied.

Ionic conductivity involves the transport of ions, as shown in experiments in which the deposit of metal from the ionic compound on the cathode is measured after the passing of current. Faraday's

n t be fl t plates but ar m t m cyl ndr cal or phe c l A c mmonly sed ı ızatı chambe h s sphe al m tal uts d h ll nd a maller m t l phe ın d B ‑w en the tw sh lls an el t pote tıal s maintain d nd the ıonızatı c rre t m ured

If ızat chamber ı t b u ed t detect the nızatio p duced by a ngl p rticl th c rr t m as rı g de e mu t b extrem ly nsı t e n the rrent pr du d e y sm ll A ıngl α-particl of 3 Mev e e gy wo ld p oduc bout 10^5 po ıtı e r $1\ 6 \times 10^-$ oul mb f cha g An mplifi mu t be u ed to ın ea th ız f the c rrent pulse so that t c n be m as ed o d play d on n osc ll cop Th e re t ı the ı zatı n chambe s pa ed thr ugh f igh ı ta (Fig) d the ltage gene at d by th c rr t the s stan ampl fied ı a h s ampl fie

The p l e f urre t ed by the ep at on f ha g ın the hamb take a mplı t d form wh h d p d n th typ f g s n the cl mb I a r the el ctrons th t are knock d ff the m lec le rap dly att h t mole ules of ygen, p od ıng neg t xyg n ı ns At m c m lec lar o m v sl wly ı the lectr field beca e f the l g ma s ompa ed to elect n I pu e m n tom ga uch g the l t n do n t att h t the t m a d th s the n g t e h ge m m h mo e p dlv th n th p t ha g So-c ll d f t t o hamb r th e m d t t ke dva t ge f th ap d m t n f lect o If lect coll t n s ed th m pl fie mu t l o b m de t re p nd t th r p d ollect n f le t The collect tıme f electr g s chamb ı ab t 1 μ S h h mb m y b ed f u t ng r tes up t 10^5 t / ec If th h e ı ns a e u ed ı t ad f le t o s th oll t o t me bo t 1 msec nd nt g ates p t 10 p r ec b obt ed

Proportional counters A l ger p l ı ob- t ed f th olt ge a th zat h mb ıs ı ed and th ele tr s cele ted s ffi tly t g ne at dd t l l t U d h d t th dev ce ı u lly called a p o- po t l t r n th m red p l e ze p port l t th g l n zat n n the g P port al nt s e lly m d w th cyl d l lect de w th a fi w tl ent l od La g n zat ch mb s 6 ft l ng a d ft d h bee ed n c m y p ıment I zat hambe ı l g nd w th the ame d m te h e bee ed ın tı g eut ı l r t B a ppe al m um ed f th lect ode a d gla pla t mbe f th l t

Fission chambers N tr s b d tect d a p ll l pl t n zat n ch mbe whı h fi l l m t l h bee ated the pl t Wh n n t n t the u leu f a fi ble t m th n l d t g tes p od g e l f g ments whı h can au e ı nızatıo ın the gas Not all the eutro e terı g such a chamber will make a ou t Som of th m will pa s tl rough the cl am ber with ut ent ng a nucl s of th fi onal le mat rıal Othe s may p duce fi on but th fis sı n f agm nts beı g f limited range may re- maı ın th lıd mate al Fı n ch mb s al way ha h gh backgr ınd or α part cle co nts becau tl e fis o able material ıs radı ctı e

[w n r]

Bibl og aphy B B R ı a d H H Staub *I nı zatı Chambe d C nters* 1949

Ionization gage

An ı trume t for mea urıng acuum by onızıng ga a d measu ng the current *See* VACUUM MEASUREMENT I ızat gages may be cla ıfied l y th me used t the g

In the h t filament ı zatı n gage el ctro s em tted by an ı a d cent filame t e attracted t w d a posıtı ely ch rg d gr d electr de Col l s f ele t ns w th gas m lecules produ e n The *ions* are attracted t neg t ely charged *elect od* Th n c rr t ı a m re f the n mber f m le ules f ga hence of the acu m (p e sur)

Fg 1 Hot fil me t t g g

Fg 2 C ld-c th d (Phl p) t g g

Ionization

The process by which an electron is removed from an atom molecule or ion This process is of basic importance to electrical conduction in gases and liquids In the simplest case ionization may be thought of as a transition between an initial state consisting of a neutral atom and a final state consisting of a positive ion and a free electron In more complicated cases a molecule may be converted to a heavy positive ion and a heavy negative ion which are separated

Ionization may be accomplished by various means For example a free electron may collide with a bound atomic electron If sufficient energy can be exchanged the atomic electron may be liberated and both electrons separated from the residual positive ion The incident particle could as well be a positive ion In this case the reaction may be considerably more complicated but may again result in a free electron Another case of considerable importance is the photoelectric effect Here a photon interacts with a bound electron If the photon has sufficient energy the electron may be removed from the atom The photon is annihilated in the process Other methods of ionization include thermal processes chemical reactions collisions of the second kind and collisions with neutral molecules or atoms *See* ELECTRICAL CONDUCTION IN GASES ELECTRODE POTENTIAL [G H MI]

Ionization chamber

An instrument used to determine the ionization produced by fast moving charged particles Ionization chambers are a type of particle detector and may be used in cosmic ray research in nuclear physics or as radiation survey instruments which indicate the level of intensity of radiation at a point *See* PARTICLE DETECTOR

When a charged particle moves through a gas it may pass near enough to an atom in the gas to remove an electron from the atom by the process of electrical attraction or repulsion This is called ionization of the gas atom Left behind are the negatively charged electron and the atom the latter with a net positive charge The function of the ionization chamber is to measure the total amount of charge separated in this way by the passage of the charged particle

Ionization chambers are constructed with two electrodes across which an electrical potential is placed The negative charge produced in the gas moves toward the positive electrode and the positively charged ions move toward the negative electrode The current of moving charges is measured to give the total ionization produced in the gas

General types Ionization chambers are of two general types those used to detect radiations from radioactive substances placed directly in the chamber and those used for detection of higher energy particles originating outside the chamber such as those from a particle accelerator In the first category α particles from naturally radioactive substances are usually detected by placing the substance in a parallel plate chamber directly on one of the plates The pressure of the gas is adjusted so that the α particles are stopped before they reach the opposite plate Such a counter gives information on the half life of the material or on the amount of active material present if the half life is known An ionization chamber used to detect β rays (electrons) from radioactive substances must be much more sensitive than an α particle counter because the specific ionization produced is much smaller Usually either a proportional counter or Geiger Muller counter is used to detect β rays (*see* GEIGER MULLER COUNTER) Ionization chambers have been used however to detect electrons and other singly charged fast moving particles from particle accelerators or cosmic ray In this application the gas must be carefully purified and the amplifiers must be of high gain and well stabilized

Electroscopes The simplest ionization chamber is the gold leaf electroscope in which measurement of the angular deflection of two gold leaves in a gas filled container indicates the ionization produced in the gas (*see* ELECTROSCOPE) Ionization chambers based on this general idea are widely used as indicators of charged particle radiation They are made in small sizes for convenience (they are often shaped like a fountain pen) and are carried by people who work near sources of radiation *See* MONITORING (IONIZING RADIATION)

Current measurement For accurate measurements of ionization it is necessary to measure the actual current produced A pair of metal plates mounted in a chamber that contains the gas in which the ionization is produced is connected to a battery and current measuring meter as shown in Fig 1 The ions produced in the gas are separated by the electric field and the current of ions is measured by the meter The metal electrodes need

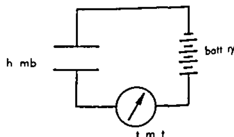


Fig 1 Ionization chamber circuit

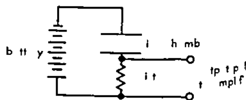


Fig 2 Pulse ionization chamber circuit

refl cti n fr m th ion phere The f ct that w ld wid radi mmun at e tr ct d to fre qu l s than abo t 30 m gacycles pe ec nd s a oci ted with the fa t that eflect on of radio wa e fr m the n pl re s n t bt ined at h gher r d f eq en ies

Refinements of investigation The h ghest r d o f q ency at whi h t i p ibl to bt i r da reflect n fr m the i no pher i a m a r of th m x mum l t on d n ty in the i o phe e Dur ng the p st quarter f c ntury n tw k f n sph r c b rvato es ha b n e tabl hed ve th w rld with th bj ct of me ing the maxi m m l tr n d n ity in the i no phe and ert i the int esti g n sph r pa am ters, s func t n f th t m f day th sea on of the ye r the latt de a d th degr e f la a ti ity It h s b en f und that the degr of oni ati n i the i n sphe s l ly d p nde t pon the z n th a gl l the su The ele t de ity is h gh when the s s ne r th z n th and g d lly d appears aft u t. P rt c larly at the highe level in th o phe the ele t n dens ty d ppe r at n ght l wly eno gh that m o at o always ex sts n the on sphe e E at the poles d ri g the pe od f p p tu l d kn me zat n ists in the n sph e The l s la ntrol of the i o ph e i nfirm d by ob erv tio s mad duri g umer us l r l ps A maj r f ctor i th i at of the i o ph the bso pt f ultra let l ght f om th n If th ult av ol t l ght fr m th u we e ot almo t ompl t ly ab bed the n ph re l f at the su fa of the rtl w ld l ad lly mod fied

Alth gh th m lati n of k wl dge con er ng the i n pher s n 1925 h bee larg ly h e d by d om th d the m a s ar a a l l fo t dyi g the o ph Th lu i o ph me n kn w a th ur r o t o o- ph ri lev l nd almo t c rt i ly as oc ated w th x itati n d on zat on f tm sph ric at m a d m l les by n m n p rticles as- oc ted with la a t ty In th ab n e of the moo d l a t f al l ght, the ll m nati n t the ground i du ed m n tly t d ati f m x i d at m m l c le the tm ph re at phe i lev l Th l m n t al p od d by d nt grat f n m g met r al o oc u t ph le el B t dyi g ll f th e phe- m it po bl to m k m r ded t g th ph c l t t f th n ph e M teo in ecent y a t ha become f s bl t d t me t d ectly nt th o ph w th th d f ock t a d tell t s Th n d bredly pen w f i ph i n estig t d ad lly h ges th mp rtan e f the n ph a p t (m n n i nm t

Gaseous character and frontiers In th no- ph th tm ph re i e t em ly te uo E n t th l w n ph r lev l th number f m lec les pe t l m bo t 10 000 t m les th n t th u fa l th rth With sc nt in the io sph re the atm ph re become rapidly mo e t nuous At h ight of 100 km the number of m lecules per unit olume is about 1 000 000 time le s than it i at the surfa e of the earth whe eas at 200 km the figure i perhaps 10 It mu t be real zed h wever that although the atm phere in the i osph r s extremely tenuous compared w th th t at the gr und nevertheless a good deal of atm sphe e st ll e i ts at iono pheric le els Thu at a h ight of 100 km th r rema n me 10 atm spher c molecule per ub c meter and f the e a f a t on of o ly about 10 are i mi ed In the i n ph r a p rti ular molecule is able to tra el a mu h greate di tan e bef re lliding with another m l ul Whereas the mean free p th of a m lecule nea the surface of the earth is about 10 met r it is about one tenth of a meter at a leight f 100 km and perhaps 100 meters at a he ght of 200 km In the h gh io ph r a mole- ule tr els m n kil meter bef r coll ding with another molecule At heights above 00 km how eve the e r ma y nkn w features of th atm s- pher Thes re under current investigation w th th d of artifici l satell tes Se ATMOSPHERE METEOROLOGY RADIO-WAVE PROPAGATIO

[H G B]

Bibliog aphy R Bolgi no (d) Inter ti nal ympo um o flu d mechan s in the ion phere *J Ge phys R ea ch* 64(12) 2037 2238 1959 J A Fleming (ed) *Te restrial Magnetism and El tricity repri t* 1949 G P Kuiper (ed) *Solar Sy em* ol 2 1954

Ion permeable membrane

A f lm o heet of s bst nce hi h is pref ren ti lly pe m abl to som species or type of i n Thi s lect ity is u ually exhit ted during elec tri al tr nsp rt f i cr s the m mb e nd r n lect ical p tent l but the term also applied to m mb a es sh wi g s le t e m t nsp rt und r pressu e or oncentrat n grad nts Tech n q e based th e membran s m y b u ed to de nize w t or th r l nts to epar te var us o specie r t carry ut electrochem al re t s wh le i lati g th pr du t f re t o

Principles M mbra es howin o l cti ity n le tri al t n p rt a e d to be p m ele ti a d are usually compo ed f s bst nc s hav g i n e l a g p pe t es Su h sul ta s h s a chem c l st u ture o p t ng fi ed ha g s tes f on charge type, positi e o neg t e, e h ne of wh ch i ele t i lly l ala e d l y a r nt r i f o p po t cha ge t pe Th unte n ad ly e ha ged fo an the mob l o f im la ha ge type x st ng th l t n urr i d g and perme ting the ion e cha ge m t l The numbe of mobile i ph in add t n t the e nter i s s go erned by D nn typ membr e eq lib m S DONNAN EQUILIBRI I ION EXCHANGE

After establ hme t f a Do n q l b i m th o ent t n f o ha g type f o w th n the

The hot filament gage is mo t useful at pressures less than 1 micron (μ) Use is limited because the filament will burn out if the pressure rises much above 10 μ Unwanted chemical reactions or ad sorption may take place on the heated surface

In the cold cathode (Philips) ionization gage a high voltage is applied between two electrodes Fewer electrons are emitted but a strong magnetic field deflects the electron stream increasing the length of the electron path and thus increasing the chance for ionizing collisions of electrons with gas molecules This type is widely used for pressures of 0 01–10 μ

In another type of ionization gage the gas is ionized by high energy alpha particles emitted l y a radioactive source such as radium

All ionization gages must be calibrated for the gas to be measured because different gases have different ionizing properties Accuracy of 10% of full scale value is attainable [B D H H C P]

Ionization potential

The potential difference through which a bound electron must be raised to free it from the atom or molecule to which it is attached In particular the ionization potential is the difference in potential between the initial state in which the electron is bound and the final state in which it is at rest at infinity

The concept of ionization potential is closely as sociated with the Bohr theory of the atom Al though the simple theory is applicable only to hy drogenlike atoms the picture furnished by it conveys the idea quite well In this theory the allowed energy levels for the electron are gi en by

$$E = -k/n \qquad n = 1\ 2\ 3$$

Here E is the energy of the state described by n The constant k is about 13 6 electron olts for atomic hydrogen The energy approaches zero as n becomes infinite Thus zero energy is associated with the free electron On the other hand the most tightly bound ca e is given by etting n equal to unity By the definition given above the ionization potential for the most tightly bound or ground state is then 13 6 electron volts The ionization po tential for any excited state is obtained by e aluat ing E for the particular value of n associated with that state For a further discussion of the energy levels of an atom *see* ATOMIC STRUCTURE AND SPEC TRA ELECTRON VOLT

The ionization potential for the removal of an electron from a neutral atom other than hydrogen is more correctly designated as the first ionization potential The potential associated with the re moval of a second *electron from a singly ion ed* atom or molecule is then the second ionization po tential and so on

Ionization potentials may be measured in a num ber of ways The most accurate measurement is ob tained from spectroscopic methods The tran itions between energy states are accompanied by the emission or absorption of radiation The wa length of this radiation is a measure of the energy difference The particular transitions that ha e a common final energy state are called a eries The series limit repre ents the transition from the free electron state to the particular tate common to the series The energy as ociated with the eries h a transition is the ionization energy

Another method of measuring ionization poten tials is by electron impact Here the minimum en ergy needed for a free electron to ionize in a colli sion is determined The accuracy of this type of measurement cannot approach that of the pectro scopic method *See* CHEMICAL STRUCTURES ELEC TRON CONFIGURATION ELECTRONEGATIVITY [C H XL]

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Ionosphere

A succession of electrically charged (ionized) layers in the earth s atmosphere above the tropo sphere and stratosphere zones In the tenuous outer fringes of the earth s atmosphere incoming radia tions from the sun ionize the gases pre ent. The free electrons thus made available render the outer mo t portions of the earth s atmosphere electrically conducting This part of the atmosphere is kno n as the ionosphere and extends from a height of about 60–80 kilometers (km) up to heights in exces of 1000 km

Bases of the concept The existence of the iono sphere was first suspected from studies of the mall variations that occurred in the earth s magnetic field These could be explained in terms of electri currents in an electrically conducting upper atmo phere The existence of the iono phere became much more certain however after Marconi had succeeded in transmitting radio waves acro the Atlantic Some means were required to explain how the radio wa es managed to surmount the curvature of the earth The possibility that an electricall conducting ionosphere could act as a mirror f r radio wa es was the most obvious explanation of Marconi s observations During the 1920s experi ments were made to detect the existence of the ionosphere by what would now be called radar techniq es In this way the existence of the ion sphe e was independently established by E V Appleton and M A F Barnett in England and by G Breit and M A Tuve in the United States In the early experiments reflection of radio waves a obtained from what is known as the E region of the *iono phere at a height of about 100 km* Later ex periment at h gher r dio frequencies showed that it i po il le to penetrate the E region of the iono sphere and that reflecti n is then obtained from a higher region known as the F region at heights varying from 200 t 500 km At still higher rad o frequencie even th F reg n i pe etrated without

membrane will exceed the other by the concentration of the counter ions Therefore the proportion of any electrical current crossing the membrane carried by the ions of the most numerous charge type may be very high and the electrical mass transfer of these ions in the direction of the oppositely charged electrode correspondingly high Membranes whose fixed charges are negative and counter ions positive are under an electrical potential preferentially permeable to cations tho e having positive fixed charges and negative counter ions are preferentially permeable to anions

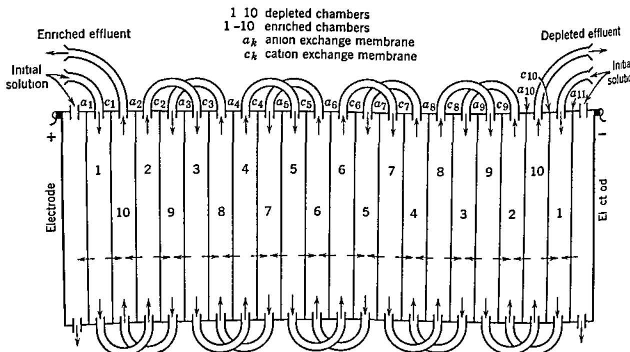
The electrical transport number of one charge type of ion in a membrane depends on the electrolyte concentration of the surrounding solution in equilibrium with the membrane This is a necessary consequence of the Donnan membrane theory and leads to the important practical consequence that the selective ionic permeability of the membrane decreases as the external electrolyte concentration increases At sufficiently high concentrations the membrane will have no electrolytic selecti ity and will serve simply as a diffusion barrier Membranes with the highest fixed charge concentration will be selective at the highe t external concentration

In addition to the electrical transport of ions across ion permeable membranes electroosmotic transport of water or solvent also takes place with the net tran port being in the direction of the counter ion movement The amount of water tran ported per faraday will depend on the properties of the ions simultaneously tran ported and on their transport numbers in the membrane Thus the net water transport i a maximum at low external solution concentrations

Measurement of transport numbers within the membranes can be made by direct measurement of ionic tran port in electrolytic cells or by mea ure ment of membrane potentials across a membrane separating solutions of known and different electrolyte concentration The departure of the mea ured potential from the ideal Nernst potential is a mea ure of the transport number of the counter ions in the membrane

Membranes The physical properties of ion permeable membranes vary considerably Ideally they should be tough and flexible readily hydrated, yet good diffusion barriers Practical membranes for electrodialysis should have low resisti ity and are usually less than 0 025 in thick For analytical measurement of ionic activitie low resi tivity is not essential The membranes may be of heterogeneous or homogeneous phy ical structure and may be internally supported by inert material

The principle application of ion permeable membranes is to electrodialytic deionization using electrolytic cells having multiple compartments separated by the membranes as shown in the illustration. Membranes labeled a_i are preferentially permeable to anions and tho e labeled c_i are preferentially permeable to cations Under an applied potential the ions in compartments 1 2 10 will migrate through the ion permeable membranes toward the electrodes into compartments 1′ 2′ 10′ Hence alternate compartments will be depleted and the others enriched as electrical current flows The alternate compartments may be joined as shown the current traversing the continuous streams n times where n is the number of unit cells A unit cell is defined as consi ting of



Schem t c d gr m of mult ple o exch ng m mb a l ctrod alys s ell Small hor zo tal r ows d te movem nt f o s betwe n c mpa tm nts

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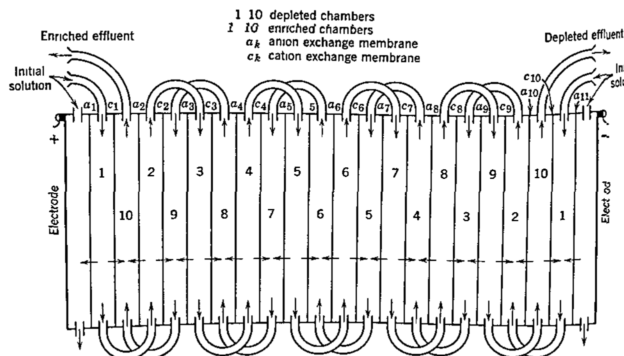
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S hemat c d ag am f mult pl o ch ng m mb a ele t od ly c ll Sm ll h r o tal w d ate m vem t of ons betwee c mpa tm ts

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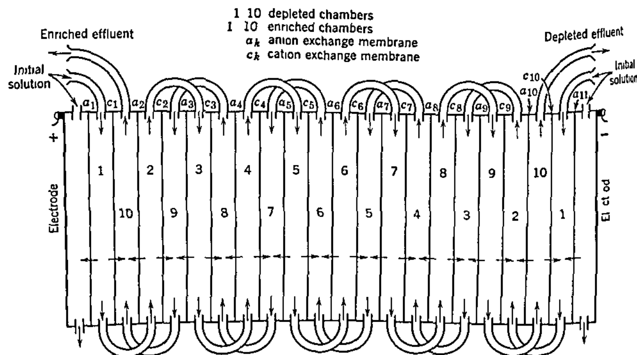
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Schemat c d gr m of m lt ple on e ch g memb a electr d lysis ell Small ho a t l a r ws d at moveme t of o s b twe n compa tments

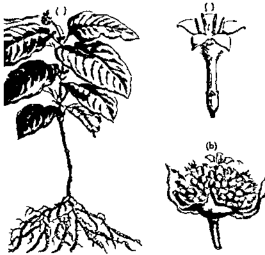
d chamber and an adj ce t co centrat d ber with the rr p di g an on perme ble cat n p rmeabl m mb ane The lectr de bers a e f d i depe dently to keep the l c e cti n prod ts par t fr m the c ted d plet d lectr lyte tream *Se* Di is ELECTROLYTIC CO DUCTANCE ELECTROPHO- SALI E WAT R RECLAMATIO

[A G W R.K.U]

bliog aphy R. K nin *Io E ha g Res ns* d 19 8 F C. Na hod a d J S hubert (d) *Ex ha ge Tech l gy* 1956

cac

w pe enn al hrub half hrub f the tr p cal t in B azil and Col mb a. Se r l pe i s a e d b t the d ied r ts nd rhizomes of *Ceph lis*



Ip (C ph l p ch) ( ) Ent pl t (b) In- fl sc ( ) S gl fl w (F om A J K M l Th N t l H st ry f Pl t H lt)

p h a t i t th m te l ecog zed as th ffi al d g. pec Med ally it sed p i p lly as a met c a d e pecto ant *S* RUBIALES

[P D S]

IR drop

Th pot u l d p d t tan e r a y p l m t (wh h t t f le tro- m t f) an lectr t. Thi pote t l d p by d fi t the p od ct of th r t e *R* of th l m t d th t *I* fl g th ugh t. Th *IR* d p es t i th d ff e c f pot ti l bet ee the tw e d of th res t r I mpl d ect-cu nt c t nta i g batt ry a d n mber f e t s, the um f ll th *IR* d p d th c r t (l d g that f th i t rn l t n e f th l att y tself) is eq l t th lect m t e f e f th b tt y Th mport t t th m sef l th lyt sol ti f lectri l tw ks.

[J W.ST]

Iridium

Chemic l element umber 77 iridium Ir in the free state s a ha d white metallic substance

Uses At o dinary t mpe at es, iridium is the m st o ro i n e i tant leme t known It s used f ery high t mp r ture cru bles pe ti g in n noxidizing tmo pher fo f rna e windings, a d a an all y ng element to t e gthen pl tin m

Chemical and physical properties The atomic n mbe f rid um 77 atomic weight 192.2, d n ty 22.54 g/cm melting p t 2443 C, boiling po nt 5300 C, nd l ct c l r ist ty 5 3 mi r hm pe c nt meter t 0 C. Rad o ct e so- t pe f th f ll wing m ss n mb a e kn wn 187 188 189 190 192, 194 195 196 197 and 198 The tabl i otope of i d um have the m ss num be 191 d 193 The nat r l bu d c of the e r 38.5 nd 61.5% pect ly Irid um i n t tta ked by a y id i ludi g aq a eg a A 30% rid um pl ti m alloy pra tic lly n luble in qu g Fu i n with alk l id zing flu es s e s ry to c ert iridi m to a oluble form Di sol ti n of r d um may l o be a ompl hed by fu g t with sodi m hlo de whil tre t ng the m lt w th hl i Th e t eme in rt s of irid um rich ll ys eate pr blems the an lysis a d refin ng Irid m hib ts al ce tates f 1+ 2+ 3+ 4+ nd p b bly 5+ d 6+ Th 3+ a d 4+ l e are the m t mm Iridium h tro g te dency to f rm c d nat n c m p ds

Metallurgical extraction O m d um bta ned n the t t n f pl tin m s fu ed w th zinc and sub q e tly d g ted w th hydr hl ric a d t n ert the m t i l to a fi p wd Th s powde s th f ed w th an lk l oxidizing flux wh ch n erts th dium t n a d solubl form Th p oced e i ely quantit t so that th nsolu bl e. d e m t b recy led Vari s hydr lyt sep r t il bl t parate the iridi m f m th r m t l Oft th in l bility of d m in le d ed t parat it from oth r p eci us m tal Th relat e lub l ty f amm n um hl dat w t m y lso b ed t ffect separ ti n. When he ted th omp d y ld m t lli d m Separat e not quantit i th l gthy cycli g of ta li g s equi ed

Principal compounds Iridium trichloride $IrCl_3$ is a green water insoluble compound made by treating iridium powder with chlorine at 500 C Sodium iridium(IV) chloride $Na_2IrCl_6 \cdot 6H_2O$ is a black water soluble crystalline solid made by heating a fused mixture of iridium and odium chloride in chlorine and then dissolving the resulting melt in water Sodium iridium(III) chloride $Na_3IrCl_6 \cdot 12H_2O$ is an olive green water oluble crystalline solid made by reducing a olution of sodium iridium(IV) chloride Ammonium iridium(IV) chloride $(NH_4)_2IrCl_6$ is a red black relatively insoluble crystalline olid made by adding ammonium chloride to a solution of sodium iridium(IV) chloride Iridium trihydroxide $Ir(OH)_3 \cdot xH_2O$ is a green black insoluble solid made by hydrolyzing a solution of iridium(III) chloride

Analytical techniques The separation and determination of iridium is the most difficult procedure in the analyses for precious metals For a discussion of sample preparation *see* SOLUBILIZING OF SAMPLES The 4+ valence state may be titrated to the 3+ valence state by the use of hydroquinone or ascorbic acid as a reducing agent Colorimetric methods using the color of iridium(IV) chloride are also used Iridium can be precipitated as the sulfide ignited to the oxide reduced to the metal in hydrogen and then weighed directly

For a discussion of the natural occurrence metallurgical extraction and alloys of iridium *see* PLATINUM *see also* OSMIUM RHODIUM [E A HA]

Iron

Chemical element number 26 iron Fe is the fourth most abundant element of the earth s crust (5%) It is a malleable tough silver gray magnetic metal It melts at 1540 C boils at 2800 C and has a density of 7 86 g/cm The atomic weight is 55 85 each atom has 26 electrons and the four stable naturally occurring isotopes have mas es of 54 56 57 and 58 The two main ores are hematite Fe_2O_3 and limonite $Fe_2O_3 \cdot 3H_2O$ other ores are magnetite Fe_3O_4 taconite (an iron silicate) and siderite $FeCO_3$ Pyrites FeS_2 and chromite $Fe(CrO_2)_2$ are mined as ores for sulfur and chromium respectively Iron is al o found in many other minerals and it occurs in ground waters and in the red hemoglobin of blood

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Oxidation of ferrous ion to ferric ion is moderately difficult in acid solution but o curs readily in basic solution because of the in olubility of ferric hydroxide The le tr de potential for the ferrous-ferric rea tion is dependent on the complexing species present in the solution Ani ns such as CN F and PO tabilize the 3+ oxidation state whereas amine such as phenanthr line stabilize the 2+ state

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tro g a ds b t th y re norm lly hydr ted a n Fe(NO)s 9H O nd f rric amm n um alum NH F (SO) 12H O Bec u e of mila ities n e a d ch rge al m n m i n nd ferric i n ha e quite a l g u chem tr e alth u h f r ic hydr ide i n t amph teri The a hyd hl r des and b o i m des h e d meric p for e mpl Fe Cl a d ataly e certa n org n c rea tio s The hy dr ted on, Fe(H O) whi h i fo d i ol t o mb n w th OH F Cl CN SCN N C O and ther n t f rm coo d nati n om plexe A th c ntr t o f i n inc eases, more gr p c mb n w th e ch c t n u t l c mb na t o ch s F Cl and Fe(CN) r re ched

Th f rrat o FeO wh ch nta n ir n in th 6+ o idat on tate i bt ed by r a t w th st g d nts s ch s hypochlo ite n alka l e sol t Salts s ch as Na FeO and BaF O e re d ly p epa ed nd fa rly stabl S lu t s o t g the ferr t i n a e r ddi h p ple a d l yge l wly i lkal e m d a d rap dly in c d

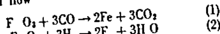
An t rest g a pe t of r n h mi try is the rray of c mpo d w th bo d t b n Ce m t te F C is a omp nt of teel The cya d mpl e f both fe u a d f rr c re ery tabl d e n t tr gl m g et c n c nt ad s t ti t m t oo d t omple e Th ya de mpl es f rm c l r d lt i cl d g th fam pru n bl e KFe (CN)₆ m d fr m f r o nd p t m ferrocy d $K_4Fe(CN)_6$ Th c mp d T rnb ll blu made from ferr u i d pot m f r y d K Fe(CN)₆ i bel eved t be de t c l t p s an bl e Th re e m y c mpo d c ta g fi ya de g p a d ther gr p (h s NO CO SO NO NH d H O) bo t the r n The c m po d N Fe(NO) (CN) 2H O e u h m po d t be ed t t t f ulfide on

The th bo yl F (CO) F (CO) a d F (CO) lso ha i to-ca bon bo d I n pe t bo yl f rmed d tly by the act o of w th bo m de d p es re the th bo yl y the ed by d ect mea Th pe t c bo yl mp d ed a sou of p S ME L C RBONYL

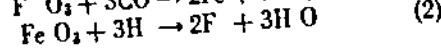
Abo t 1950 w t pe f i mp d w s d sco e ed Cy l pe t d ca e t w th r n d t g d y l p t d yl F (C H) M y li ti th f th mp d lled f oc l bl The t ct i th t f t m bet ee tw ymmetr l pe t g l g th b g g t m d th ame sa d h mpo d F h r m k bl th rm l t t l t S O c O IET LIC CO IPOU D M d t es f f rroc with b t t e t g p tt hed t th g bo a e k n th h m t es m th l f g t th t f F r c be l ed t th f oc m F (C H) d l t g th h been p p red S Lo N CKE TR ITIO ELEME TS [J O E.]

Iron (extraction from ore)

I on is extr cted from ron ore and concentrates by pyr metall g cal p o s e ba ed up n the appli c t o f heat and redu ing g ses At temperatures of 700–1100 C, r n o des s ch as hematite (Fe O) and m gn t te (F O) the principal i on beari g mi er l a e r ad ly reduc d t metal lic r na f llow



$$F\ O_3 + 3CO \rightarrow 2Fe + 3CO_2 \qquad (1)$$



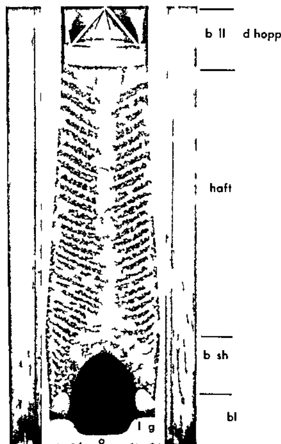
$$Fe\ O_3 + 3H \rightarrow 2F + 3H\ O \qquad (2)$$

M gnet te is s milarly red ced

Red cti n s car ied out n blast fur ace and in so-c lled di e t edu t on pr e e The bl t f r nace pr ce produces m lten pig iro c nta n n bout 4 0% c rb n a d a total of approx mat ly 3 0% f ma g e e sili on a d pho pho u wh ch m st be la g ly r mo ed n th onv r on of pig o nt teel the p n ipal o tlet fo ir n Direct pr e s s p rate at l wer temp r t re nd there f re p od c old red ed ron wh ch is relati ly free f c b n a d the metal noted abo e These metal re form d a d ll y d with the iron at the highe tempe at re wh h pr a l e r the b tt m f the bl st furn ce The term d rect pr e im plie that th s old reduced i an b u ed d rectly the p od ct n of teel by m lt ng a d w th ute ten r fi g

The blast furnace process The bl st fur ace p c the mo t effic ent a d m t e on m cal m a yet d el ped f r prod c g large t nn ge of m lte p g i n wh h an be c t i to seful h pe refi ed i to teel Short p mit e f r n ces wh h we perated pr r t ab ut 1350 p d ed l w a b n d the fo m lle ble on c lled wr ght ir which ould be fa hioned i t eful a t cle by h ting a d h t wo k ng The pe t on of the hort f rnaces w int rupted per od c lly t rem e the lid met l whi h c tai ed mall pe nt ge of occl ded slag H ghe temp r t re mo e st gly educ n c ndit n a d th l ng time req ed f r smelt ng r acti t o r in larg f rn s p oduc d c rb ri ed nd l quefied i o nd l qu d lag f m th r g g e d th fl Th pr d t n f l qu d p g n d sl g a c t o s pe ati n marked the beg ng f th bl t f rn c p cess Th tran t f om th p od t on f wr ght n t pig w the r lt f the d l pme t f quip- m t wh ch p ded mean f f cing t ng bl t f t deep b d f f el a d the p d t f c mb st pw d th ugh n ly g l mn bed f aw mate ial t g f c k d fl The bla t f rn e t th f of a h tt f d ct d melt g ch mbe p mp d o ga p od cer

Th g r l h pe d gement of th ch g bl t f rn h wn i Fig 1 h lf e t f a model f n ce I rd t a o d m g of es h l f d p d per m b l ty l d r h rged l yers Th dark



Fg 1 A ra g m t of materials i f nace mod l

layers represent the relatively coarse coke and the white layers the charges of relatively fine ore This layered arrangement is inherent in finer size of the ore its steeper angle of repose and the flow of material off the conical shaped bell when it is lowered to discharge the raw materials from the hopper shown at the top of the model Liquid iron and slag collect in a bottom cylindrical section called the hearth The lighter pear shaped areas near the top of the crucible correspond to combustion zones Preheated air is forced into these combustion zones through water cooled copper castings called tuyeres

An in erted frustrum of a cone located immedi ately above the hearth is known as the bo h The formation of molten pig iron and slag in the bo h permits a gradual reduction in cross secti nal area at lower level The upper part of the furnace called the shaft i conical except for hort cylin drical section Widening of tl e shaft at lower levels permits the charge to move downward with out mechanical bridging a it expand upon l eat ing Additional cro s ectional area at lower levels of the shaft al o permit a lower de ent of the charge and a longer re idence time at temperatures where ore reduction and other metallurgical re actions occur Similarly more area in the wider ecti n of the furnace reduce the elocity of the a cending ga e pr longing ga l d c ntact

Structurally the furnace con i t of a steel hell lined with fire l rick to con er e l eat The l o h and hearth are water co led t maintain the refract ry lining The trend is to u e carbon lining in the hearth and bosh and to in ert bronze cooling pl in the lining of the lower part of the haft Modern furnaces are about 28 ft in diameter in the hea h are about 31 ft across the widest ection and taper to about 21 ft at the stockline An over all height of about 95 ft provides a working volume of sh t 50 000 ft^3 Such furnaces consume 1100-1500 tons of coke per day and produce 1300–2400 tons of pig iron per day depending upon the iron content of the ore used the coke required per ton of iron and the physical character of the raw material Ore of high iron content reduces the amount of coke a d stone (fluxing materials) required per ton of pig Replacement of coke and tone with ore increases the weight of iron per cubic foot of charge An increase from 50 to 60% in the iron content of the ore will for example introduce about 30% more iron per cubic foot of over all charge

Permeable charges permit larger volumes of gases to move through the stock column more uniformly without building up pressures which support the charge and prevent it from settl ng regularly Under such conditions a larger volume of blast can be applied more coke can be burned the charge will ettle more rapidly and more pig iron will be produced In general beds compo ed of particles of uniform size will offer less re i tance to the flow of gases

The value of uniformity in the size of the coke has been fully appreciated for many years because coke occupies about 60% of the volume of the charge Pieces smaller than ¾ in are normally d carded for furnace use by screening the coke im mediately before charging Care is taken to blend the coals available to obtain a strong coke whi h will not fracture into small izes upon handling prior to charging or in the furnace

Size preparation of raw materials Since 1956 the large capital expenditures required to build new l last furnaces and the pre sure due to infla tion to increa e the productivity of exi ting fur naces have stimulated a pronounced intere t in the ize preparati n of iron ore and concentrate The depletion f high grade depo its has nece itated the benefi iati n of l w grade dep its and the production of concentrates that must be agglomerated before they can l e i ed in the bla t furnace During agglomeration mall sizes are converted to larger lumps by the applicati n of heat which form poro mas e by grain growth and cau e slag l onding without complete fu ion Alth ugh the use of agglomerated c ncentrates is increa ing large tonnage of direct hipping ore containing 5? 60% Fe will l e a ailal le for at lea t e eral decades Thi ore can l e i ed effecti ely in the l la t furnace providing coar e es are cru hed to about ? in a d particle maller tl an ? in are agglomerated l y sintering Tl i pr dure eliminate particles in a ize range whi h offers high re i tance to ga flow and al greatly red tl e am unt of fine ore ca i d off a flue d t

A rec nt development ı t incorpor t flux s ıch a calcıum xıde o m gn ı m xıde nto ɀglom ated m t r al ın the form of ı regul rly ıaped ter o sph rı l pellets Pellet are proıced by h at g w t ball mad f m fin ly d d d nc nt ates Th prod ctio of s lf fluxıng ag me ates may lead to two-comp nent charge cons stıng of coke and self fluxın agglom rates or t th ee comp nent charges of coke sc eened re and self flux ng ggl merate I comp rı on with th n ızed e cha g u ed n the past these mo e ıde l ch rg s of ızed mat rıal will make ıt p ss ble to bu n about 30% more coke per day per f ırnace a d to n r pr d ı t on accord ngly

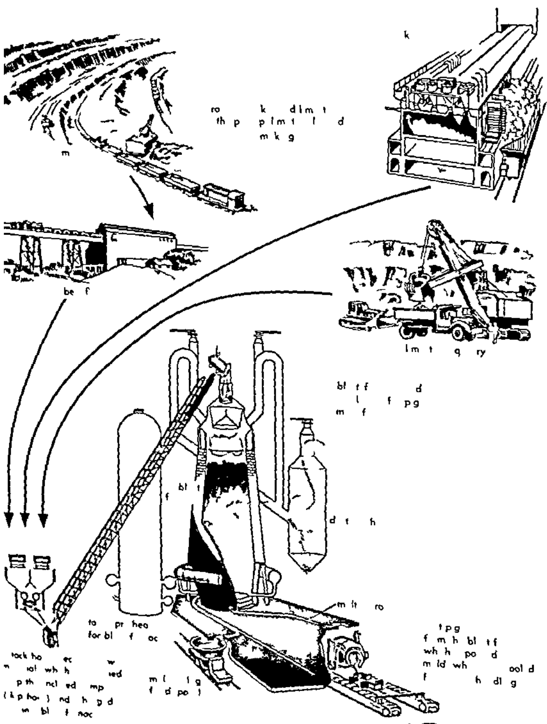


Fig 2 S ps i h bl t f na p oc ss f ir e t ctio (Am I a d St I I st t t)

The use of oxygen enriched blast containing balanced additions of steam is another promising development which will permit more coke to be burned in furnaces of all sizes. This will be possible because less gas is made per pound of carbon gasified with oxygen enriched air and steam as shown in Eqs (3) to (5). Coke burning rates may be increased well in excess of 30% by the use of oxygen enriched air and steam in conjunction with sized iron bearing materials. If the quantity of iron per cubic foot of stock is increased 30% by the use of richer ores and these high iron charges are then moved through the furnace 30% faster production will increase by 69% (1.3 × 1.3 = 1.69).

Reactions in the furnace Heat and reducing gases are released near the base of the furnace by the combustion of coke. Because air contains about 79% nitrogen N and 21% oxygen O_2 combustion in a deep full bed can be expressed as follows



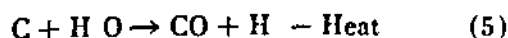
$$2C + O_2 + 3.76N_2 \rightarrow 2CO + 3.76N_2 + \text{Heat} \qquad (^{79}/_{21} = 3.76) \qquad (3)$$

The products of combustion when using dry air consist of 34.7% carbon monoxide CO and 65.3% N_2[(5.76/2.0) × 100 = 34.7%]. Two moles of coke carbon require 4.76 moles of air. If the air is enriched from 21 to 30% O_2 by the addition of manufactured oxygen the combustion reaction will be as follows



$$2C + O_2 + 2.33N_2 \rightarrow 2CO + 2.33N_2 + \text{Heat} \qquad (^{70}/_{30} = 2.33) \qquad (4)$$

With this degree of oxygen enrichment only 3.33 moles of blast will be required to gasify 2 moles of carbon C and the products of combustion will consist of 46.2% CO and 53.8% nitrogen



$$(2.0/4.33) \times 100 = 46.2\%$$

By the elimination of inert N oxygen enriched air provides a means for burning C at faster rates for increasing the reducing power of the gas and for increasing flame temperatures.

Air normally contains some moisture which reacts with carbon as follows

$$C + H_2O \rightarrow CO + H_2 - \text{Heat} \qquad (5)$$

Recent experience has proved that when moisture is added and higher blast temperatures are used to compensate for the heat absorbed by reaction (5) smoother furnace operation and higher productivity result. The hydrogen H and CO produced by reaction (5) dilute the N and increase the reducing power of the gas permitting the ore to be properly reduced even though it descends more rapidly. Oxygen enriched air has a similar effect.

Substantially all of the heat for the process is either introduced in the blast which is heated to temperatures of 550 950 C or is released by the combustion of coke in localized zones before the tuyeres. Nitrogen carbon monoxide and hydrogen which leave the combustion zone at temperatures of 1700 1900 C carry heat to the overlying column of stock. Gases leave the top of the furnace at 200 C. More permeable areas receive more gas and are thus heated to a higher temperature. Efficiency of heat transfer as well as efficiency of reduction and other smelting reactions depends upon the degree of uniformity of gas flow through the stock column. The recent trend toward the use of high percentages of sinter pellets and sized ore with the gradual elimination of all unscreened ore will increase efficiency and productivity and permit closer control over the composition of the metal.

Control of pig iron composition The carbon content of the iron is fairly well fixed at about 4.0% because the iron is saturated with carbon. However higher percentages of silicon tend to lower the solubility of carbon in iron. Because all the phosphorus and about 75% of the manganese in the charge are recovered in the pig iron these elements are largely controlled through the selection of the ore. Silicon and sulfur are controlled by adjustments in the temperature in the crucible and by regulating the composition of the slag through the addition of varying amounts of limestone. An increase in the temperature of the hearth will raise the silicon and lower the sulfur content of the iron. Hearth temperatures are regulated by the amount of fuel used by the temperature of the blast and by the addition of steam to the blast Eq (5). Variations in gas flow and in the transfer of heat from gases to solids result in uneven heating of the charge making it difficult to control the temperature of the hearth.

Direct processes Although direct processes have been subjected periodically to extensive study research and investigation on a pilot plant scale since 1920 they have thus far failed to compete with the blast furnace in supplying an economical source of iron for steelmaking. However the present outlook for such processes to succeed in more favorable localities is brighter than in the past. Imported ores and concentrates of low gangue content are now more readily available for producing a solid reduced iron that will not produce excessive amounts of slag in steelmaking furnaces. Techniques for reforming nonreducing hydrocarbon gases such as methane into CO and H_2 have been improved. Substantial progress has also been made in the development of fluidized bed techniques which permit the flow of reducing gases through beds of finely divided ore or concentrates in counterflow processes which are more efficient thermally than older processes. The generally high prices of steel scrap since World War II have stimulated interest in direct processes as a means for producing a cheaper source of metallic iron for steelmaking. Current developments which show great promise in increasing the productivity of blast furnaces will have an important bearing upon the price of steel scrap and the future competitive position of steel scrap direct process iron and pig iron. *See* CAST IRON; COKE; IRON; IRON ALLOYS; MINING OPEN CUT OR PIT; ORE DRESSING

PYROMETALLURGY STEEL MA UFACTURE WROUGHT [T.S.J.] IRO
B bl o aph J. W Frankl n Indu try look at d rect reduct Eng M n J 158(12) 84-93 19 U.S. Steel Corp The Mak Shap and T atn e of St l th ed., 19

Iron alloys

All ys l ir co t n g th l ment in amo t ary g l m few pe nt t p rhap a fu h 85% d d ff re ti ted f m a t ron nd te l by comm epta ce i th ind try F r p rpo es of n enie e th e n b gr uped by the r c m m l appl atio i th foll win e teg ries magn t all ys lectri l res tan e all heat res t g all corrosi n resi t ng all and th rm l-expa n all s

The mbe f po bly u ful ll y a d th r hem l gradati i n rm At le t 20,000 so-called en in ri g all y n l ding both fe d n nf rr h been des ribed, and new es a e bei g added con ta tl Th d n h been lim ted t some f th bett r kn wn types of e h gr up these dent fied by trad names alth ugh t h uld be bor e mind that in ma y i t nces all s f th ame compo ti n ar l ble f m d fferent prod ers under the n mes. An ll y may be at t mes des ribed b an unquali fied n me nd a s le mpos t n lth u h it i pres tat f series the m mbe f whi h re i pra t e m s pec fi ally ident fied b let t s mb rs Ea h of th m mbers a modifi ti f th rigin l mpos ti n and des gned t at f som p rt l r equ me t F m ple I l s i k l-ch m um all y containi app im t l kel 15% ch om um d r n. Th t mod fied n th f I n I X b th dd t n f m ll cont lled mo t f n, Fe al m m Al, t t m T a d colum b um (n b um) Cb t mp t gth nd h d es nd t r d t u pt bl t g hardenin In the se f I on I W the properties ar com pa bl t those f I c n l X, alth h col m b m h been l mi ted l l 00 o th ther h d t in abt t 28 cobalt, Co nd 3% m l bdenum M a d ha dened w th al mi um a d t t n m lt exh b t good eep d rupt e p pert es t ll temperat es espec all t 1,00 F d a d h been sed f first tag tu b n blad g j t lt e n es. The I coloy gr p l col Incol T a d I coloy 901 h t mpl f a series f mod fied all

Magnet c alloys Magneti all ms be broadly l fied u der tw he d g nretent e r m g et c lly soft d retent (perm nent) r m g etically h d s di ted n T bl 1

Th soft all bec me m gnet zed a magnet fi ld, b t l d m g eti ed wh n th fi ld i emoved Th r g f m a t ro whi h th pos est, t th r n k l ll ys, wh h re the best l lud th well kn wn lectri al (l con) teel These soft all y fi d w dest appl t on n modern commun cation and electrical power equipment and a e the most important on the ba i of qu ntity prod ced Th y are ordinaril u ed n th wro ght t te

The retent e o hard all ys remain magnetized after appl ti n of a m gneti field Alth ugh produced in les r quantity they e the old r f th tw groups These allo are mpl ed wher a con tant magn ti field s requ ed and where t i impract al to establ h an lectrom gn tic fi ld. Th are u ed in the wrou ht r ca t tate or re pr p red by the nterin proces wh ch i espe all u eful n makin mall magn t Some of the Alnico m be ther ca t or i t ed

Some allo especially f the soft gr up a well as ther magn tic m t rial pos e ertain fe tures th t make them pecul arl ted f pec fic applications F r e ample the perm abil ty f the allo s co taining about 30% n ckel 70% iron, uch s the Carp nter Temperature Compen ator 30 varies li rly with temper tu e They a e u ed hunt in electri al a d th n truments to compen ate f amb nt t mperature ari ti n Other ll uch a P rm n a Conpern k and I operm xhib t relatively con tant perm ab lity dependent f field tre gth, and are wid l em pl ed n c mmunicati n rcuit

Alth u h th soft all ys a e gen rally used a sol d metal they ar som times empl ed in the fi ely divided condit n in co es in nd ta ces in t l ph and rad o-frequency rcuits whe e the min m ze edd curre t losses The f rrom gnet oxides are u ed fo mil purposes. Two impor tant dev l pm ts f recent ears are th ceramic perm ent m gn t m teri l uch s Ferr m g l and the pec ll proces ed and h at t eated 3% s licon ir n exh biting cub o tent tion. S e MAGNETIC MATERIALS M G ETISM

Electrical resistance alloys These ll are best known a th h ating el m nt in uch famil i r h useh ld t ms a r d tion h ters electric r nges and toa t The most comm nl used al l y f r thi purpo the 80 20 n kel-chromium type It has an cell nt combinati f electrical and mech n cal p operties a d good res tance to x d t n t tempe atures up t 100 F

Th re re al o a number of r n-co t in ng al lo a li ted in Tabl 2, that f nd wide appli at n in thi fi ld Th most popular of these contain 60% ni k l 16% hromium, the bal nce ron 38% n k l, 19% hrom um th bal iron and 22% chr m um 5% al minum 1% b lt, the balance iro

For som ppli at n th la t type uperior t even the 80 20 n ckel-chr mium all y It maximum ope ti g tempe atu (pp ximatel 430 F) and it es tri t are high and t l s a l g serv ce lif Becaus f a tendency in service to i ase length w th t m (grow) d a rel ti el low tre gth wh n h t, heatin el ment made f th all require good mecha i al upport.

The use of oxygen enriched blast containing balanced additions of steam is another promising development which will permit more coke to be burned in furnaces of all size This will be possible because less gas is made per pound of carbon gasified with oxygen enriched air and steam as shown in Eqs (3) to (5) Coke burning rates may be increased well in excess of 30% by the use of oxygen enriched air and steam in conjunction with sized iron bearing materials If the quantity of iron per cubic foot of stock is increased 30% by the use of richer ore and these high iron charges are then moved through the furnace 30% faster production will increase by 69% (1 3 × 1 3 = 1 69)

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PYROMETALLURGY STEEL MA UFACTURE WROUGHT [T L J]
1970

B bl og aphy J W F ankl n Indu try look t d ert ed ctt n *Eng M t g J* 158(12) 84-93 19 7 US Ste l C rp *Th Mak g Sh p ng a d Treat g f St l th d* 19 7

Iron alloys

All y f i on o ta n g th eleme t i am unt y ng f om a f w per c nt to pe hap high s 85% and diff nti ted f m ca t iron a d teel by t e mmo a cept nce n th nd try For p po e of co enc they an b grouped by the c m me al appl c t n th following ateg ie magn ti all y ele t i al r ta c all ys h at e ti g all y ro ion esi t ng lloy and th rm l expan n ll ys

The numb r f p bly u l l all ys nd th r chem al g l t o s i en rm s At l a t 20 000 o-called ng eering all y i cl d ng both fer r u a d no f r ou h been d bed and new es ar be ng added o tantly Th s d c i n ha been l mited t m f the better kn wn type f ch g p th ar dent fied by t ade ames Alth gh t sh uld be born n mind that n m ny in t nc s llo s of the am mp iti n a a il bl f m d ff t p d s der the ames An all y may be at t me descr bed by an quali fied nam d gle omp t alth ugh it i r pre tati e f a e ie th memb r f wh h r n p act e mo e p fi ally dentified by l t t numb r E h f the m mb rs s m d fi ati n f th g l c mpo it n nd s d g ed to s t sfy s m p rt ula q em nt F r exam pl I n l i a k l ch m m lloy nta n g app x m t ly 77% n k l 1 % h m m a d 7% Thi m d fi d th f I on l X by the dd t f m ll ntr ll d amo r f o F l m m Al tit ni m Ti nd ol m bi m (n b um) Cb t mp l gth d ha d nd to r nd it eptible t ge hard n g In th a of I l W the p p rt ar m p r bl to th of I l X lth ugh f m l m h b n l im n t d l l 00 th other ha d ta n ab t 28% ob lt Co d 3% m lybd m M d r h d d with lum m nd t ta m It e hib t good ep a d ptu propert at ll t mpe atures espe lly at 1600 F a d r d h s b en ed fo fi t t g tu bi e l lad g n jet a ft g n Th l ol y group I l y I l y T and I c l y 901 th r e ple f m *l mod fi d ll ys*

Magnetic alloys Magn ti ll y may be bro dly l fi d nd tw h ad g r t t r m g et ally oft a d t nt (p ma nt) r m g ti ally h d d t d in T bl 1

Th ft lloy be ome m gn t ed in a m gn ti fi ld b t a e e ly d magnetized when th fi ld mo ed Th a g f m a t i n h h i th poo est i th i o kel all y wh h the be t nd ncl d th well k ow l t l (il) t l Thes oft lloy find wid t ppl a ti n n modern comm ni ation and el ctr cal powe equipment and are th m t important n the ba s f quant ty produced They are rdinar ly u ed in the wr ught t te

Th retentive r hard all ys r mai mag tized after appl cati n f a magnetic f ld Alth ugh pro du ed in le er q ant ty they are the older f th tw gr up Th alloys ar empl yed wh r a c n ta t magneti fi ld i r quired and where it i mpractic l t establ h an elect magnetic fiel l They re ed in the wr ught r ca t state or are p epared b th nt ring proce whi h i e pe cially u eful in mak ng sm ll magnets Some of th e Aln c s may be th r ca t r inte ed

Some all especially of the s ft group a w ll s oth r magnet c material po es certain fea t res that make them pecul arly uited f r pecific appl cat n F r x mpl the p rm al l ty f th alloy co tai ing about 30% n ckel 0% ir n s ch as the Carpent r Temp rature Compen at r 30 varies l ne rly w th temp ratu e Th y r u ed a h nt in electri al and ther in trum nts to ompen te f r ambient tempe at r ar at n Other alloy uch a P rmi a Conp rn k d I p rm e h bit a relat ly n tant perm al il ty and p dent f field tre gth and ar widely em pl yed in commu icati n ir u t

Alth ugh th ft alloy are g er lly ed a s l d met ls th y ar m time employed in the finely di ided cond ti n core i indu t nces in telephone and rad o-fre ju ncy c rcu t wh re th y m nimi e eddy c rr nt l es The fer m gnetic ox de a e u ed f r m lar pu po es Tw imp r ta t devel pments of ec nt year re the ceramic p rm t magnet m teri al i h a Ferr mag l and the specially p oce ed and he t tre ted 3% s l n i on e hib ti g cub c or nt ti n S MAGNETIC MATERI LS MAG ETIS I

Electrical resistance alloys These all ys are best known s the h ati g el ment i s ch fam l i h u eh ld item as d t on heat r el ctric anges and t a t rs The most ommonly u ed al loy f r th pu po e i th 80 20 nickel-chr mium typ It h s an e c llent mb nati n f electrical and mechan al p opert and g d i t n e to o d t n t tempe at s up t 2100 F

The r also a number f i on-c nta ing l l y l ted n Tabl 2 that find wid pplication n th field The m t popul r f th e o tain 60% n ck l 16% h omi m the bala e i on 38% k l 19% h om um the balan and 27% hr m um 5% alum num 1% c balt th bal a ce i o

Fo me a ppl at ns the la t type pe ior t e en the 80 20 nick l-ch m um alloy Its maximum perati g t mpe ature (approx mately 2450 F) d ts e i t nt e h gh e a d t ha l nge ervice l I Becau e f tend ncy i r c t a e n l ngth w th t m (gr w) nd a r l ti ely l w t ngth when hot h at ng le m t m de of th all y q g od me ha al pp rt

Table 1 Magnetic alloys

Name	Percentages								Remarks
	Fe	Ni	Co	Cu	Al	Ti	Si	Other	
Hard alloys									
Alnico I	Balance	21	5		12				Wide range of applications
Alnico II	Balance	17	12	6	10				High *BH* product
Alnico III	Balance	25			12				Can be cut and ground without chipping, low cost
Alnico IV	Balance	28	5		12				High coercive force
Alnico V	Balance	14	24	3	8				Oriented, highest *BH* product of known alloys
Alnico VI	Balance	15	24	3	8	1.25			Oriented, high coercive force, low residual magnetism
Alnico XII	Balance	18	35		6	8			Highest coercive force of any Alnico
Cunife	20	20		60					High coercive force, machinable and ductile, high cost
Indalloy	Balance		12					17 Mo	Sintered product
Vectolite								30 Fe_2O 44 Fe O 26 CoO	Highest coercive force of any material except Alnico XII, sintered material, lightweight
Ferromag 1								BaO 6Fe_2O	Extremely high coercive force, ceramic type, lightweight
Soft alloys									
Puron	99.95								Magnetic standard
High Si Iron	Balance						4.5		Power distribution, audio transformers
Cubex	Balance						3		Cubic oriented
Low Si Iron	Balance						1.0		Intermittent duty motors, relays
Hipersil	Balance						3		Transformer cores
Nicalloy	Balance	47							High permeability, power tran[illegible] [illegible] field
Permalloy	Balance	78.5							Sensitive direct-current apparatus, relays, high permeability, low hysteresis loss
4 Mo Permalloy	Balance	79						4 Mo	High frequency and electrical apparatus, high permeability and resistivity
Hiperco 35	Balance		35					1 Cr	Electric motors and generators, high saturation
Permendur	Balance		50						Apparatus operating at high flux density, high permeability at high flux density
Vanadium Permendur	Balance		49					V	A[illegible] very high saturation and magnetostriction
Perminvar	Balance	45							M[illegible] transformers, high and constant permeability
Isoperm	Balance	40							High and constant permeability
Supermalloy	Balance	79						5 Mo	Communication transformers, high permeability
Mu Metal	Balance	74						5 C[illegible]	Shields and audio transformers, high permeability
Carpenter Temperature Compensator 30	Balance	30							[illegible] permeability [illegible] with temperature [illegible] compensat[illegible] [illegible]
Conpernik		50							High and constant permeability [illegible]

Table 2 Elect ical resista ce alloys

N m	Fe ntages F	C	Ni	Co	Al	Oth	R m k
Alcres	B l e	1			5		Res t o d t n c 100 F
Al hro	Bal n	16			5		Res t d t n t 100 F
Alu h om O	B la ce	30			5		Res t xid ti n t 100 I
B l o	B l e		0				Self regul tors l y t perature
Nicl m A		0	80				Res ts x d t n t 100 F
Chrom l C	B l ce	16	60				Res t l t n to 1800 F he vy d ty rheostat
Chromel D	B l ce	19	3				Res ts d tion t 1100 F
D m t	Bala ce		46				Coppe ;l ted es t n e ll y f sealing in l ad n lect l gl t l lts and r d o t bes
F rropyr	Bal ce	7			7	1 Mn + S	Res ts dati t 100 F
Ill m G	6	22	58			6 Cu 6 M	Res t nce ll y t sev rely rros tn os pl eres
K th l A	B l ce	3			6		Res ts d t t 100 F
Smith 10	Bala ce	38			8		Res ts d t i t 100 F
T ph t C	Bal n e	1	61				Res ts x d t t 18 0 F

A Fren h all y by th m conta ns 5% n bala ce k l d is used i lt ge res tors.

In the elect cal a d lectr n c field the all y d the p fic ses s me f wh ch a e ind c ted Table 2 F x mple the 70% ck l 30% pe u ed i th rmom t r bulb and oth r appli t n q i ng h gh temp ratu e ffic nt l s t n e a ll y ntaini g 60% n kel 16% h m um a d th bala e i on i pa t ula ly ted f h y d ty rheo t ts b c u e of it ab l ty t th t d h gh o rl ads Se RESISTA CE, ELECTRICAL RESISTANC HE TING

Heat resisting alloys In the choi e f alloys for igh t p rature s r i h m cal re sta ce r o t f th req r me ts Not only m t the m a tal i b ta t ally etain t g al id ntity in the tmo ph e nd i th temp t f op ati n b t it m t al p ffi nt t ngth and hock t e t meet rvi e qu m ts The t rm h gh temp t e erv e implie d ff rent th rmal cond t o b t f r th alloy d u ed ll ect a m m m t mp ratu e f 1000 F ha b ch n Ab e thi p t th t nd rd Am ri a Ir n and St l I tit t (AISI) d t nle teel a ith t appl c bl they p e l m tat o s n me h i l p p ties

F m ny ye r ll y l gh ni k l ch om um d c l lt w r kn wn nd employ d in the ch mi l d try but du Wo ld Wa II n d d ma d f ll y t w th t nd h gh t mp ratur f s h ppl ati n a xha t t u p r h ge ft g e lt d n th de l pm t f wh t tod k w h gh t mpe tu m tal som f wh h a e d bed T bl 3 Th b adly cla s fied n ba c balt ba or n k l base d pe d g upon th pred m at ng l m t Som e mployed n the ast tat th r e w o g ht d st ll the s m y be util z d th th w ght a t f m

D l y A 286 d th R fract l y re e am ples f th fir t l They h g d t ngth up t b t 1350 F d t f t ry x d t n es t a e t 1500 F and find th ir prin ipal ppl ca t n s t rbi e blades h o d ng (l at l ld g) a d t l o es f jet eng nes

The cobalt ba all y with t d temper t res up to about 2100 F The r ex ellent trength a d id ti n a d c rr sion re tan e at the h gh temper t res mak th m s itai le f r per harg r buck ts and nozzl vanes Their high t however pre nt th r u e fr m b ng eco om c l unt l temper tures in excess of 1300 F ar e ntered

The n ckel b e lloys ha e c llent ox dat a d corro on r si tance up t 2 00 F The Inconels (N m n s in England) a e ad antageou in cycl h at ng and cool ng ervic wh re larg tem p ratu grad ent ex t Some ar p ecipit ti n h rd n g and de el p ve y high el ated t mper tu e trength The Ha t lloys co t n rel ti ly l rge mou t of m lybden m and find e pe ial se in hem l equipm t that p e ated in cor ro en ronm nts

Corrosion resisting alloys The t rm c o on i t g a ge rall n ed n th e tion t the e ta to attack by l quid a d ga s other tha a xygen Th int s ty of h att k dep ndent up n many f cto s for ex mpl the all ys c nc ned th p t cul med um nder on d at n c nt ation and id ng r redu ng nd tion A larg numb r of th all y on d ered s c rro on res ta t ntain on in am unt ary g f m 2% t e 50% N kel and ch o m m a comm n tit nt tog ther w th 12 l % m lybde um b lt pre C tu g t n W nd s l n S

Be u e of th many f t rs inv l d n ngle all y i a a l bl th t w ll d q at l e t all f rm of o i n There h s b large v r ty f lloy mp t u ed b t only a few e d crib d in T bl 4 It i oft n po s ble to find e th t w ll t l t app x mat ly at fy a y g n t f omn i l req i m ts F exampl

Duriron a cast silicon iron alloy (15% Si) is widely used in reaction kettles for handling acids and alkalies but it is quite unsatisfactory in resisting hydrochloric acid

Durichlor another cast silicon iron alloy of approximately the same silicon content and containing molybdenum may be used to resist this acid In like manner Hastelloy C which may be cast or wrought is noted for its excellent resistance to hot and cold solutions of most highly corro i e mineral acids

Many of the corrosion resistant alloys are heat resistant and the borderline between the two groups is often not clearly demarcated *See* CORROSION

Thermal expansion alloys Table 5 li ts a few important members of a group of iron containing alloys having unique thermal expansion properties

Table 3 Heat resisting alloys

Name	Percentages					Form in service	Upper limit of service typical applications
	Fe	Cr	Ni	Co	Other		
					Iron Base		
A 286	Balance	15	26		0 2 Al 1 15 Mo ⌞ Ti 0 ? V	W	1300 F turbine blades afterburners
D scaloy	Balance	14	26		3 Mo 1 ⌞5 Ti 0 ? Al	W	1350 F turbine wheels and disks bolts
Incoloy	Balance	20	3		0 5 Cu 1 5 Mn	W	000 F resi ts sulfur attack and green rot
Multimet	Balance	21	20	20	3 Mo 3 5 W 1 Cb + Ta 0 15 N	C	1500 F turbine blades jet and combustion chambers
Refractaloy 26	Balance	18	37	19	3 Mo 3 Ti 0 3 max Al	W	1450 F turb ne blades and parts
					Cobalt Base		
Haynes 21	2 max	28	3	Balance	6 Mo 0 3 C	C	?100 F turbosupercharger buckets
Haynes 25	2 max	20	10	Balance	14 W 1 5 Mn 0 15 C	W	1800 F turbine blades afterburner parts
S-816	4	20	20	38 min	4 Mo 6 W 4 Cb	W C	1500 F turbine blades
					Nickel Base		
Hastelloy X	Balance	2⌞	45	1 5	9 Mo 0 6 W	W C	⌞ 00 F jet engine tail pipes afterburner components turbine blades
Inconel	Balance	15	74		5 Cu	W C	00 F exhaust manifold afterburners
Nimonic 90	5 max	20	Balance		1 ⌞5 Al 5 Ti	W	1?00 F turb ne blades afterburners
René 41	5 max	19	Balance	11	1 5 Al 10 Mo 3 Ti 0 01 B	W	1800 F turbine blades afterburners
Ud met 500	4 max	18	Balance	17	3 Al 4 Mo 3 Ti	W	1750 F gas turbine components
Waspaloy	1	19	Balance	14	3 5 Mo 2 5 Ti 1 2 Al	W	1900 F tu bine bl des afterburners

W wrought C cast

Table 4 Corrosion resisting alloys

Name	Percentages						Remarks
	Fe	Cr	Ni	Si	Mo	Other	Rema ks
Alloyco	Balance	20	29	3	3	4 Cu	Ac d and alkal resi tant pumps v lves
Durichlor	Balance		1	14 5	4		HCl e tant
Duriron	Balance			14 5			Acid (except HCl) and alk l re s stant
Hastelloy B	5	1	B lance	1	8	5 Co 1 Mn 0 4 V	R sts HCl and bo l ng H PO
Hastelloy C	5	16 5	Bal nce	1	17	2 5 Co 4 5 W 0 4 V	Resists SO P O and Cl and H_2SO at h gl t mp
Hastelloy D		1	Bal nce	9	1	1 5 Co 3 Cu 9 25 Si	Res sts HCl nd H SO
Illium G	Balance	2	58		6	6 Cu	Ac d re sta t (nclud ng H SO)
Pioneer Metal	Balance	⌞5	3		5		A id res tant
Worthite	Balance	?0	⌞4	3	3		Re i t H SO and weak HCl

T ble 5 Th rm l-e p ion lloys

N m	P ce tages					Coeff t of expan n	R n ks
	Fe	C	Ni	Co	Oth e		
I	Bala ce		36		0 35 C	Low	B t l ther st t l ngtl t d t l m ng tapes
K a	B la ce		29	17		Com a glass	Vacu n t bes
N l a	B l ce		36			Low	Bim t ls tl most t l ngtl tand rd n ea u ing tapes
N Spa C	B l nce	55	4		4 T 0 6 Al	Con ta t nodul f l t ty	
N Sp Lo	B l ce		5		4 Ti 0 6 Al	Low	
5 N Span-H	B lan	9	29		4 Ti	H gh	

Th all y of the In ar type nta g bo t 36% *nickel the b lan* i o ha e an ext emely low c ffi nt f therm l exp They a e sed as ods a d tap s f geodet wo k c mp n ating pend l m b l c wh els i lock d watches and in del c te in t um nts They a e al m pl y d whe l w xpan n all y ope t with y high e p s ll y to a m em nt with t mp rat r cha ge a in b netal th rm l t bes nd r d a d tube rm ed n temp ra r g lat r

Of especi l i e t th N Span s ri f al l y Th on i kel ge ha d n lloys t in ng ab t 2% tit n N Span Lo exh b ts l w oeffi e t f exp io N Sp H s the *e e nd the* c effi i nt h gh A th rd Ni Sp C h a n t nt mod l f ela t cit a d u ed for sp i g n pr n *n tr ments f r* hair p i g i k s d watch d f r b u d n g et b s.

I the m n f ctu of a t u type of a u m t bes wh re i m t b m d b tw gl a d m tal p l *pa o h* t t s a nti l *n th* lloy mployed mely th t the e p urv s b m l to that of gl s a d th t th y e h b t h gh d g ee f thermal shock K p t a B y p e i g thes p pe i A t appl at n of th all y its u e *fo th m u t g g f d d m s l d ne m d f P, oce am the new fam ly of y t ll ne m t r l n d f m gl* S THERMAL EXPANSION l ALLO CAST IR N STEEL WROUGHT IRO

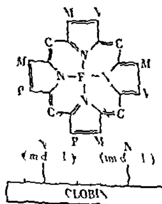
[J J E R F]

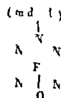
Iron metabolism

Th m t bol m f r n di c s ed n th rticle with r spe t t ts r le in the ryth cyt red blood *ll a d* ts ab pt f m the i t stin l tr ct

Erythrocytes The d ell f bl od c n tit te abo t 40–50% f th total blood. The mamm l n e yth oc t t pp x m t ly 32% hem glob n 60–65 ate nd bout 8% t m the me h w k w thi hi h th hem gl bi s i t m t ly h ld Th yth yt f med i th d b e m tr w nd p s th gh ev l pha e b fo e tran e nto the blood The phy ol g cal stimulu f r the prod ct on f *erythrocyte* is a l ering f the xyg c ntent f the blood in the bone mar *row* Th r po e of th b ne marrow con titutes n f the mo t important a p ct f a clim tiza t on t l fe t h gh altitud s *The e ythrocyt s are* u derg g *continual d nt g ati n* mo tly in the ple n b t to me e te t in the bon ma r w and ther ret c loe d thel al *is su capable of* phag ocytic act on The br akdow of hemogl bin in *thi p ce l sd t* the *release of iro and th f* mati n of b le p gments The a erage l f pan f e ythrocytes is ab ut 1 0 d y f *r man 100* days f r the d g a l 39 day fo th ch cken S HEMATOPOIESIS

H moglob the e p ratory p ote n of vertebrat erythrocytes is a c njugation of an ir n





H m gl b f gments

H m gl b f gm ts (A Wh P H dl E L *Sm th D St tte P pl f B o h m stry M G w H ll* 1954)

porphyrin compound (heme) with a basic protein (globin) Four atoms of iron and four heme groups are present in the hemoglobin molecule

The porphyrins are all derivatives of porphin a ring structure composed of four pyrrole groups linked by —CH= (methene) bridges The ferroprotoporphyrin of hemoglobin contains methyl groups (M) in positions 1 3 5 and 8 (see figure) vinyl groups (V) in 2 and 4 and propionic acid groups (P) in 6 and 7 In each of the ferroprotoporphyrin groups of hemoglobin an iron atom is centrally located bound to the four nitrogens and to imidazole groups of globin Combination of hemoglobin with oxygen probably involves a displacement of one imidazole group in each ferroprotoporphyrin moiety Different hemoglobins among different vertebrates differ in the amino acid structure of the respective globins

Synthesis of the protoporphyrin of hemoglobin require only two precursors glycine and acetate The glycine supplies all of the nitrogen and eight of the 36 carbons The utilization of acetate involves the intermediate formation of a succinyl derivative arising from the decarboxylation of α keto glutaric acid a component of the citric acid cycle with which the synthesis is closely linked The mechanism for the incorporation of iron is probably an enzyme reaction The essentiality of copper to iron utilization is well established

Metabolic breakdown of hemoglobin released on disintegration of the erythrocytes involves oxidative cleavage of the porphin ring at a methene bridge to form linear pyrroles the bile pigments Very little of the iron of heme is excreted most of it being used again in hemoglobin formation or being stored as ferritin Biliverdin a green pigment is first formed and is the main pigment in the bile of some animals but in the human bilirubin (red) is the main pigment The bile pigments are removed from the blood by the liver and are secreted into the intestinal tract in the bile where they undergo further chemical changes Some of the intermediates in these reactions are reabsorbed and either returned to the liver or excreted in the urine to form its pigment urochrome See BILIRUBIN LIVER

Iron metabolism Iron metabolism relates to iron liberated from functional combinations (for example the heme proteins) in the tissues and that absorbed from the intestinal tract The efficiency of iron absorption is not rated highly however it is impossible to measure it accurately because of the bilateral exchange of iron between blood and the intestinal lumen Whatever its origin iron is transported in combination with a plasma globulin (transferrin) in the ferric state to the liver spleen or bone marrow where it is released as ferrous iron to unite with a protein apoferritin in the presence of oxygen to form ferritin Ferritin contains tightly bound micelles of a ferric hydroxide having the approximate composition $[Fe(OOH)_8(FeOPO_3H_2)]$ its iron content is variable and may reach values as high as 23% The iron released from transferrin may be incorporated into protoporphyrin to form heme and into the prosthetic groups of various enzymes as an iron porphyrin complex Hemosiderin another storage form of iron combined with protein is found in the tissues in increasing amounts as the tissue iron increases beyond the normal physiological levels

The excretion of iron in the urine is normally inconsiderable Its excretion from the skin is continuous and may be important in the daily iron economy of the body Iron released from transferrin in the blood of the subcutaneous capillary bed combines with the proteins in the dermis and is carried slowly to the surface of the skin as the cells of the epidermis desquamate The replacement of the epidermal layers in man is a slow process See BLOOD HEMOGLOBIN [H B VL]

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Iron silicon alloy

A soft (easily magnetized) magnetic material Iron silicon alloys are used principally as the magnetic core materials in power transformers The yearly product is valued in the hundreds of millions of dollars

Although silicon contents up to 6% have been employed the material most used now contains about 3% silicon The highest quality is obtained by a combination of (1) purification especially with respect to nonmetallic impurities such as carbon oxygen and sulfur and (2) control of the processes of rolling and annealing so that the crystallites composing the sheet are aligned with a favorable crystal axis parallel to the length of the sheet For a list of properties *see* MAGNETIC MATERIALS [R M BO]

Ironwood

Any of at least ten kinds of tree in the United States which are commonly known as ironwood Because of uncertainty as to just what tree is indicated the name ironwood has been abandoned in the latest check list of the native and naturalized trees of the United States Probably the best known of the ten is the hornbeam *Carpinus caroliniana* Some of the others are *Ostrya virginiana* eastern hophornbeam *Bumelia lycioides* buckthorn bumelia *B tenax* tough bumelia *Cliftonia monophylla* buckwheat tree and *Cyrilla racemiflora* swamp cyrilla or swamp ironwood All of these species except *Ostrya* are restricted to the southeastern United States Others commonly called ironwood are *Eugenia confusa* redberry eugenia of southern Florida and the Florida keys *Exothea paniculata* butterbough of southern Florida and *Ostrya knowltoni* Knowlton hophornbeam of southwestern United States Leadwood *Krugiodendron ferreum* a native of southern Florida has the highest

pec fi grav ty f ll woods native to the United States and l o kn wn s bl ck ironwood *See* FOREST A D FORESTRY TREE [A H G]

Irradiation isotopic

The bjection f a mate ial to adi t n fr m rad t e sot p (r di i t p s) fo the ape i t d other purp e (s e RADIOI OTOPE) Al th gh only rr di t n b ad ctı e t pe ı treat d in th rt le m ny th r f rm of rad a t n r ed for ı r dati n F mpl se ULTRAVIOLET R DIATION (BIOLOGY)

Th re e tw type of t pic ir ad t on In th fi t the ur f rad t on is pl ed n a cap- le In th ec nd th rad o t p ı d sp r ed n th m te al t be ı rad ted Enc p l ted rad a t on u es are ed t teril ze f d t ff and b l gı al t pr d changes ı pla tı and ther mat r al nd t a d n m d c l th apy Ir ad t on w th dı p r ed ı otopes la g ly on fi ed t ertaı proc du es f m dic l th r py n wh h a h rt l ed t pe admı t ed t a patient

Th dı t fr m ad et sot pe produ es esse t all th ame ffe t a th rad at on from h gh lt g p rt le I r t r th the h ı of a ad o sot p o high ltage ma h n de- pe ds prima ily on n en en e and ost A rad o- ı-ot pe ad t ure d not r quire the ex t e and ompl m hı ry neces ry f a h gh lta rad t ure Rad oı ot p ad a tı h wev a n t be turned n and ff and nsequently req e lab r t held ng for h lth p ot ct p ırp es

At th p e nt t m balt 60 s by f r the m t omm nly u ed ad ı t pe f r en ap lated d t n ou c lth h m 13 offe s on de bl p m e p ıma ly bec e ıt ı an bu d nt fi n p od t C ı m 13 a l bl n l rg qu t t s ı th p oces ng of f l leme ts f m nucl a t (NL E R FUELS REP OCESS- ING) I deed th ppl at n of e um 137 to l t n m l me f th pr blems f d s po- g l dı t e w tes f om the pe t n f nu le a t

I d e-131 d g ld 198 w d ly d in the dı p l t h q A h rt l ed ad t pe dm n ı d h bly p r fie l f rm o lly r nt a ly n th a f od e-131 ı jected ll dsl f rm dı e tl nt a tum in th a of g ld 198 Th pec fi d ı g l nt al th apy w th d 131 th t the thyr d gl d nt at th l m nt iod n Co eq tl e t f m l th r d d de a d e ma b t ı d b the dm n t at n of la g amount f th sot pe S R DIATION B OLOGY RADIO SC TOPE (BIOL G) [C L B]

Irregularia

Th n m g en by G C e ın 1817 ı a as m ll g f echı d wh h the nu nd p pro t l ı d tl p al t m th mb la al pl tes remain imple the primary radı les are follow and th r g d t t l ow mo e or les bilateral symmet y J D rl am and R Mel ille (19 7) ha e hown that the pyga ter d I regularia tem fr m Late T ıa c pedı d wherea the other I reg ı lar a ev dently aro from Early Jura ıc Echina cea The Irreg ılaria re tl er f re an artificial a mbl ge of milar b ıt unrelated f rm and the name c n ha e n taxonomı val dity S e DIADE MATACEA ECHINOIDEA PYGA TEROIDA REGI LARIA [H B F]

Irrigation of crops

The artifi ı l ar pl c t n f wat r to the soil to produce plant growth Ir ıgatı n in some form has been pract ced ınc b f re the dawn of written h tory In the Un ted State about 30 000 000 acre f crops ı und r irrigatı n

Use of water by plants All gr wing plant ı se water c ntinuou ly Tl rat f u e ar e h we er with th ag and kind f cr p grown and th tem p atur and other atm ph r e c nditı n Growth of crops und r irrig tı n ı t m lated l y ptimum mo tu c ndition d retarded by es e r deficient m t f water

Co d tions ı flu nc ng th amo nt of water ı ed by plant incl de ı ch fa tors as cl mat a ailable wat r supply so l truct e t p g aphy and cul t ral pr ct ces M ı h ır gat n wate ı l t l y evapo t n f om l a d water s rface or ı t an p red by plant These proce es in mb na t on re called c n umpt e e or *evapotr n p ı a t*

The term ı rigat n equı m nt me n the am u t f wat r e ded to grow a crop exclu ive of nat ral raı fall Incl ded in th requirem t ı wat r ed n t an p ration by plant evapora t on f om the soil and water urfac deep perco- latı n below th *root z n* nd ther wa te which ann t be econom cally a ided An ırrigation r q ır me t f 18 ı w uld indic te ufficie t water to c ve th c p are t th t d pth

Water requirement The qu ntity f water re- g dle of it our e equ ed to grow a c op unde normal fi ld o d tions ı called the w ter req r ment It n lud ır ıgat on w t and natu al r nf ll

C ops ha e a p ak per d of wate u e dur ng the g w g se on Irrigatı n s t ms must be pl n ed to me t the e pe ods ıf th water supply

Table 1 Cons mption of w t by various rops

Crop	Co mpt							
	Ap l	M y	J	J ly	A gu t	Sep- tem be	Oc to- be	Se so
Alf lf	3 3	6 7	5 4	7 8	4	5 6	4 4	3 4
Beet		1 9	3 3	5 3	6 9	5 8	1 1	3 3
Cott	1 1	2 0	4 1	5 8	8 6	6 7	7	31 0
P hes	1 0	3 4	6 7	8 4	6 4	3 1	1 1	30 1
P tatoes			0 7	3 4	5 8	4 4		14 3

is limited either in total quantity or rate of delivery The consumptive use of water by crops has been determined by soil moisture tudies or computed by well established statistical methods for many parts of the country Table 1 shows how this varies by months during the growing sea on The data presented in this table are for various locations and for different years and cannot be applied specifically

Plant–soil water relationships Soil of root zone depth is a storage reservoir for water used to sustain plant growth How often this reservoir mu t be refilled by irrigation is determined by the storage capacity of the soil depth of the root zone and water used by the crop Table 2 shows approximate amounts of water held by soils of various textures and availal le for plant use See Table 2

Table 2 Amount of water in soil available to plants

So l t tur	W ter c p ty n /ft f l ptl
Co rs dy l	½–⅜
S dy lo m	1⅓ 1⅓
S lt l m	1⅜ ⅓
H avy l y	1 o mo

Soil conditions po ition of water table and other factors exert strong influences on root zone depth Table 3 hows approximate root zone depths in well drained uniform soil

Table 3 Appro imate root zone depths for various crops

Crop	Root n d ptl ft	C op	Root n l pth ft
Alf lf	6–10	I tal	3
Co	5–6	C s	1–
Cotton	4–6	Tr es	5 10

Quality of irrigation water The quality of irrigation water is determined l y total concentration of soluble mineral salts sodium bicarl onate and such other sub tances as may be toxic to plants

Growth of plants is affected by olul le salts since they restrict their ability to absorl water from th oil When sodium alts are ad rl ed by oil unfavoral le c ndition de elop wl ich re trict the entrance of water into plant prevent plant emergence from the oil and make cultural practices difficult

Accumulated solul le alt can be rem ved from the oil by leaching with irrigation water which moves them l el w the crop root z ne r into drain Adver e sodium condition are alle iated l y tl e u e of gyp um l arnyard manure and leaching

Methods of irrigation Water i applied to crop by surface furrow l y sprinkling or by ul irrigation method Surface irrigation with furrow i a common means of applying water to r w crop The flow carried in furrow l etween tl e r ws of plant perc lates into and replenı hes tl e soil re ervoir Howe er on slope water carried in fur row may re ult in soil ero i n The safe f rr w stream may be approximately computed by the formula $Q = 10/S$ in which Q is the of furrow stream in gallons per minute and S is the lope of the furrow in percentage Maximum length of furrow depends on the ize of the furrow tream and the rate at which water is ab orbed by the soil Flow control to furrows is accompli hed by tubes spiles or gated urface pipe (Fig 1)

Corrugations are small clo ely spaced furrow u ed in the irrigation of close growing crop They are often employed on soils which cru t badly when flooded

Flood irrigation is a method of surface application which may be carried out with border trips basins and contour or bench borders or by flooding from contour ditches

Border trip irrigation is accompli hed by advancing a heet of water down a long narro area between low ridges or borders the moi ture enters the soil as the sheet advances The trip between borders mu t be well leveled and the grade must be uniform to prevent ponding The ridges are usually low and rounded o that crops can be grown and harvested on them This method is well adapted to close growing crops and pa ture but it is al o used for row crops Hay and grain can be irrigated on slopes up to 3% and well e tabli hed pastures up to 6% Slopes below 1% are le s l able to erosion damage and the uniformity of application is usually l etter than on steeper lope Border strip irrigation when well designed and operated is economical of both lal or and water

Ba in irrigation is adapted to flat lands It i done by flooding a diked area to a predetermined depth and allowing water to enter the oil uniformly through the root zone It is u ed for all types of crops including orchards It is al o economical of labor and water

Contour or l ench border irrigation is u ed on uniform gentle slopes with moderately deep soil Border trips are placed acro s the slope on s it al le grades The width of each strip hould remain



F g 1 Irrigot on of ow c p (b ets) by meo of sipho t b to co t ol to och f



Fg 2 f g t of w p by m f l g p kl s. T p g phy t o thl F ld t p mt th e f urf m th d

th me th o gh ut t l ngth d b m d n mult pl of the u ual w er p m ch n ry The t g t proce th ame a fo b d tr p r bas n irrig t d pend g n wl th r th t p l p s l l

Flo d g f m nt d t h s t a mmon irri gat n m thod f r cl e g w g crop and pa t re fa d ith un top g phy wh h s d ffi ult t h p f th r m an f w te appl t n F eld d t h r l ly sp ced l ng the ont ur f th l d W t r t d rt d f m th m t flow r the nt rve t ge pa ea

Sp nkler gat n d ne by means f p pe f e th t d t w te fr m a pump g pl nt to late al l e l g wh ch e l ing p kler he d a e sp ed t app p ate interv ls Lat al l nes moved f om t m t t m a m t e r q re t f th r p r met O e typ f p nkler s p rlo at d p pe a me n of w ter ppl a n p rti ul l o ch rd (F g 2)

Ad t g s of sp kl r gatt n a e les h e of l ros n n t ep slop s iform ppl at n n m t so l typ ntr l f wate meet e p d m nds, d gat n with t l nd hap g

Some d d a tage f p t kli g high t l tme t nd h gh lab r a d p rati g o t d s t n l pr nkl p tt rn by w d nd wa teful evapo ati n r t t h t d y cl m tes In some e n w sp kle y t m de ig a d b tt r m th d of m g p p h gr tly ed ed l bo d perat g co t

Irrigation in arid and humid areas Th e ge f g ted r p till e a g n both rid nd h m d reg l A eg n the l mit ng f tor is ften l ck f w ter not f la l ar a to be irr gated Howe er irrig tion pr gramming i f ten ea i r wh n the farmer does n t depend on n tural ra nfall f r cr p g owth Good y ll are obt ned by maint i ng high d f rt l ty and good so l t lth and by u ing g d r p v riette

There s little difference in the princ ple of cr p prod ict on under irrigat on in hum d regi ns and in arid one The programming of water applica t on i m re diffi i lt n hum l ar a h wev r be cau e natur l precipitati n ca n t be pred ted ac curat ly Climat c nditi n u ually m ke th spr nkler method of irrigati n m re prof tal le in reg on of h gh a rage annual rainfall Se AGRICULTURAL MACHINERY AGRICULTURAL OIL AND CROP PRACTICES PLANT WATER RELATIONS OF TERRACING (AGRICULTURAL)

[T D W]

B bl ography O W Is ael en *Irrigat o Prin i pl s a d Pr ct c s* 2d ed 19 0 A St ff rud (ed) *W t r* USDA Yearbook Agr 1955

Isanomal temperatures

At t mper tures r th rs su h as *soil o* a tem pe t re that h w equal departures fr m m ta dard Th s t ndard u ually i th l ng t rm a e age tempe at re f r ach pla e but may be the a ge f r an ent re a ea r the ag f r th plac s lat tude

Severity of a umm r be t wa e can be hown by a m p of t mper ture anomal es—differ nces f th average tempe at res f a ingle week m nth r se on fr m the long t rm a erages f r that pe ri d Pla es with the me d partures o an malies a e j ed by n mal l nes

Fr m l ng term a e ges f monthly r easonal temp at re t many pl es n the w rld th a er ag temp r ture f r each lat tud nal band can be c mputed D ffer ce b tw n these l t t d nal av e ag and tho at ndi d l p nts can l m a t mp rat re a maly map to how the effects f o tine tal ty S AIR TEMPERATURE CONTINENTALITY WEATHER AND CLIMATE [A C]

Isentropic flow

The fl w f fl id s i ntr pic when it entr py id tic l at ll poi t in the fl w l entr p fl w n be app ched f r fluid flowing ther in duct r v the t ide s face of a body Be ca e the entr py f the flu d i a thermodyn mic pr perty mil r t th enthalpy or energy f a fl d th al e f th e t opy is fixed by th t te f th fl d For a pu e ub t n e in the b nc l gra ty pilla ity l ctr c ty and magneti m t py s a f cti n f two indep nd nt p p t f r ex mpl th pre su e and t mpe atu e f r ngl ph s flu d (THERMODY AMIC PR NCI PLES)

O f the mplest xamples of ntr pic fl w f a fl d thr gh a nozzle where the flu d i ac ele ted to h gher loc ty by pre r g ad t Th fl w clo ly ppr x mat d by th

is limited either in total quantity or rate of delivery The consumptive use of water by crops has been determined by soil moisture studies or computed by well established statistical methods for many parts of the country Table 1 shows how this varies by months during the growing season The data presented in this table are for various locations and for different years and cannot be applied specifically

Plant–soil water relationships Soil of root zone depth is a storage reservoir for water used to sustain plant growth How often this reservoir must be refilled by irrigation is determined by the storage capacity of the soil depth of the root zone and water used by the crop Table 2 shows approximate amounts of water held by soils of various textures and available for plant use See Table 2

Table 2 Amount of water in soil available to plants

So l te tur	W t p c ty /ft f l ptl
C ly l	1½–3
S ndy lo m	1¼ 1½
S lt l m	1½ – ½
H y l y	1 – r m

Soil conditions position of water table and other factors exert strong influences on root zone depth Table 3 shows approximate root zone depths in well drained uniform soil

Table 3 Appro imate root zone depths for va io s crops

Crop	R t e d pth ft	C p	Root d pth ft
Alf lf	6–10	P t t es	3
Co n	5–6	C es	1
C tton	4–6	Tr es	10

Quality of irrigation water The quality of irrigation water is determined by total concentration of soluble mineral salts sodium bicarbonate and such other sub tances as may be toxic to plants

Growth of plants is affected by soluble salts since they re trict their ability to absorb water from the soil When sodium salts are ad rbed by oil unfavorable condition develop which re trict the entrance of water into plants pre ent plant emergence from the soil and make cultural practices diff cult

Accumulated soluble salts can be removed from the soil by leaching with irrigation water which moves them below the crop r ot zone or into drain Adverse sodium conditions are alleviated by the u e of gypsum barnyard manure and leaching

Methods of irrigation Water i applied to crop by surface furrows by sprinkling or by sub irrigation methods Surface irrigati n with furrows i a common means of applying water to row cr p The flow carried in furrow between the rows of plants percolates into and repleni hes the s il re ervoir However on l pe water carri d in furrows may re ult in s il er ion The safe furrow stream may be approximately computed by the formula $Q = 10/S$ in which Q is the safe furrow stream in gallons per minute and S is the slope of the furrow in percentage Maximum length of furrow depends on the size of the furrow tream and the rate at which water is absorbed by the soil Flow control to furrows is accompli hed by siphon tubes piles or gated surface pipe (Fig 1)

Corrugations are small closely spaced furrows used in the irrigation of close growing crops They are often employed on soils which cru t badly when flooded

Flood irrigation is a method of surface application which may be carried out with border trips basins and contour or bench borders or by flooding from contour ditches

Border strip irrigation is accompli hed by advancing a sheet of water down a long narrow area between low ridges or borders the moisture enters the soil as the sheet advances The strip between borders must be well leveled and the grade must be uniform to prevent ponding The ridges are usually low and rounded so that crops can be grown and harvested on them This method is well adapted to close growing crops and pasture but it is also used for row crops Hay and grain can be irrigated on slopes up to 3% and well establi hed pastures up to 6% Slopes below 1% are le s liable to erosion damage and the uniformity of application is usually better than on steeper slopes Border strip irrigation when well de igned and operated is economical of both labor and water

Basin irrigation is adapted to flat land It i done by flooding a diked area to a predetermined depth and allowing water to enter the soil uniformly through the root zone It is used for all types of crops including orchards It is also economical of labor and water

Contour or bench border irrigation is u ed on uniform gentle slopes with moderately deep soils Border trips are placed acro s the slope on suitable grades The width of each strip should remain



F g 1 I igatio of row c op (beet) by m of sipho t b to o t l th flow to ach f ow



Fig 2 Irrg ti f w er p by m o of vol g spr klers. Topog phy is too this fi ld t per it th se of urf m thods.

the sam th gh t t le gth and be made n m luples of the u l w-cr p ma hinery The irrg ti proc s i th ame a f border trip h in irrigat n, d p d g on whether th t p l pes r s lev l

Flood g f m nt u d t hes i common rr g tion method f cl e-gr wi g crop and pa t re land with es n topography wh h is d ff It t hap f oth m n f w te ppl cati F ld d t hes e losely p ed l ng th nt u of the land. W ter d erted f om them t fl w er th interve ing crop a a.

Spri kler irrig i d by me n of p pe lines th t condu t wat from a p mping plant t lat al lines l g which rev lvi g prinkl h ad a sp ed t appr pri t i tervals Lat r l lines are moved f m t m t t me as m ture eq e-ments of th cr p e m t. O e type of spri kl uses pe f rated p p m f w t ppl tion, p rti ul ly in ha d (F g 2)

Ad nt es of prinkler rr g tion a e less han f so l ros on teep l pes, un form ppli t on m t l types c t l f water to meet p d m d d irr gat n with ut l d shap g

Som d d ant ges f p inkli g h gh it l m estm t d high labo d pe t ng ts, d s-tortion f sp kle p tt rn by wi d and wasteful evapo ti ates h t dry lim tes I me e new p inkl y t m des gn d bette m thod of moving p p h g e tly reduced l bo d per t ing ost

Irrigation in arid and humid areas The e ge f irrig ted cr ps st ll ncr g both rid d h mid r gi l rid em th limiti g fa tor i ft n la k of water not f land are t be irrigated H wever ir ig ti n pr gramming i f ten e ier wh n the farmer does n t depend n natural rai f ll for crop growth Good y eld are obtai ed by m taining h gh s il fertil ty and good soil tilth nd by ng good cr p vari ties

Ther i littl differ n in the principles f cr p production der rrigat n in hum d r gi n and in arid es The progr mmi g of water applica ti n i m re d ffi ult in l mid a a h wever be-au e nat ral p ecip tati n ca n t be pred ted ac curat ly Cl m tic c d tion u ually mak the pri kl r method f irrig ti n m re pr fitabl in eg n of high a er ge ann al rainfall *Se* AGRI CULTURAL MACHI ERY AGRICULTURAL OIL AND CROP PRACTICES PLANT WATER RELATIONS OF TERRACING (AGRICULTURAL)

[I D W]

Bibl g phy O W I rael en *Irrig t n Pri ple a d P act c s* 2d ed., 1950 A St ff rud (ed) *W t r* USDA Y arbook Agr 1955

Isanomal temperatures

Air temper t res or oth rs uch s soil or se t m-p rat res that h w eq al d partu es fr m some st d rd Th t ndard u lly i the l ng term a erage temperat re for e h pla e l t m y be th a rag f n ent re rea or the rage f r th pla l t tude

Sev ty of a mm r he t wa e c n be sh wn f y a m p of tempe at re a omalies—d fferen es f the er g temperatu es f r ngle week m th o se son f m th l ng t rm ave ges f r that pe-r od Pl es with the same d partures r n mal es are j ined b isa mal l es

F m lo g term erages of m nthly aso l t mpe t r t ma y places i the w rld the er ag temperatu f r e h latitudi l b d e n be c mputed D ffere es between these lat t d nal a rages a d those t nd id l po nt can f rm a tempe t re a m ly map to show the ffect of continentality S AIR TEMPERATURE Co TI EN TALITY WEATHER AND CLIMATE.

[A C.]

Isentropic flow

The fl w of a fl d entr pic when t ent py is id t al at ll po ts i the fl w Isentrop c flow n be app a hed f flu d fl wing th r n a d t er th uts d f e f a body B ca th ent py f the fl d i a thermodynami pr p rty s m la t the nth lpy o e gy of fl d the v l f the nt opy s fixed by th stat f the fl d F p b t nce n the absen e of g ty ap ll r ty lect ty a d magnet m en tr py fu t n of tw ndepe d nt p pert es f e ampl th p e u nd t mpe t f r a gl phase flu d (se THERMODY AMIC PRI CI PLES)

O e f th mplest mples f tr p fl w of a fl d th ugh zzle wh th fl d i a celer ted t higher loc ty by a p es e gr d t Thi fl w closely app x m ted b the as-

is limited either in total quantity or rate of deliv ery The consumptive use of water by crops has been determined by soil moi ture studies or com puted by well established tatistical methods for *many parts of the country Table 1 shows how this* varies by months during the growing eason The data pre ented in this table are for various loca tions and for different years and cannot be ap plied specifically

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Table 2 Amount of water in so l available to plants

So l te ture	W t cap ty in /ft f d pth
Co rs dy so l	½
S dy lo m	1½ 1½
S lt l m	1½ – ½
H a y l y	1½ m re

Soil conditions po ition of water table and other factors exert strong influences on root zone depth Table 3 shows approximate root zone depths in well drained uniform soil

Table 3 Appro mate root zone depths for various c ops

C op	Root zo d pth ft	Crop	Root o e d pth ft
Alf lf	*6–10*	*Potatoes*	–3
Co n	5–6	G sse	1
Cotton	4–6	T ees	5–10

Quality of irrigation water The quality of irri gation water is determined by total concentration of oluble mineral salts sodium bicarbonate and such other sub tances as may be toxic to plants

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Ba in irrigation is adapted to flat lands It i done by flooding a diked area to a predetermined depth and allowing water to enter the oil uni formly through the root zone It is u ed for all types of crops including orchards It is al o eco nomical of labor and water

Contour or bench border irrigation is u ed on uniform gentle slopes with moderately deep soil *Border trips are placed acro s the slope on suit* able grades The width of each strip hould remain



Fig 1 I gation of ow c op (be t) by m a of s ph n t b s to co t ol the flow t e ch fu w



g 2 I igat f w p by m f I g
kl rs. T p graphy t th fi ld to
ermit th use of rf m thod

h same th gho t t le gth a d be mad in
m ltiples of th u al row-c p mach nery Th
rrigati p oces th me s f bo de t p
ba i rigat d p d g o whether the tr p
l pes ri ler l

Flood ng f m t d the i a c mm t i
g m th d f l e g wi g cr p and p tu
l d with ev t pog aphy wh h i difficult
t sh pe f oth me f wate appl cat n
F ld dit he e cl ly p ed al g the o t ur
f th land W te i d ted from them t fl w
ov r th i terve i g cr p a.

Spri kler irr g t o i do e by m ans f p p
lines th t co d ct w ter fr m a p mping pl nt t
lat ral lines l ng wh ch re l ing p i kler head
a pa ed t approp te i terval Late l l ne
e moved f m t me to t me as m t qui
ments f th c p a m t On typ f sp kl
uses pe f r ted p p a mean f w te ppl
ti p rticul ly rcha d (F g 2)

Ad t g s of p i kl g t o are le s
han f so l r n n t p l pes unif rm
appli ti n m t s l types c trol f water
t meet p d m d d rrig t w th t l nd
sh p ng

Som d sad tage f sp nkl n h gh ti l
n estm t and h gh labo d op t g o ts d
t rtion of pri kler p tt rn by w d nd w t f l
evapo t rat i h t dry l m t I m ca e
new sp nkl y tem des gn a d bett r meth d f
movi g p p h e gr atly ed ed l bo a d p t
ing co t

Irrigat on in arid and humid areas Th e ge
f rrigated p s t ll n ea g n both rid
d hum d egi ns. I a d gi n th l m ti g f

to i often l ck of water n t f lan l a ea t l
ir gat d Howe er irrigati n pr grammi g i of
te ea ier when the farmer does n t d pend n
natural r i fall for rop gr wtl Cood yield are
obtained l y m intai i g high s il fert lity and
good oil tilth and l y u ing good r p varietie

There is l ttle diffe en e in th p inciple f cr p
production under irrigat n in l umid reg n and
in arid ones. The pr gramm ng f water appli a
ti n s m re diffc lt in h m d are l owever l e
c u natural precip tati n c nn t l e predi t d a
cur t ly Climat c c nditi n i ally m k th
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CULTURAL MACHI ERY AGRICULTURAL OIL AND
CROP PRACTICES PLANT WATER RELATIONS OF
TERRACING (AGRICULTURAL)

[I D W]

Bibliogr phy O W I raelse *Irr gat n Pri ci ple d P act ces* 2d ed 19 0 A Steff r d (ed) *Wate* USDA Yearbo k Agr 1955

Isanomal temperatures

Air tempe atu r ther h a so l or ea tem p rat res that h w equal departu es f om m t d d Thi tandard u ally i the long t rm a erag tempe at e f r ea h place but may be the a age f r an ent re re or the a erag f th pl s l tit de

Se rity of mm r h at w e an be h wn by a map of tempe t re n mal es—diff r nces f the a er ge t mp atu es f r a gle w k m th o se n from th l ng term averages f r that pe riod Pl es with the ame depa t res r an m lies re j ned by i an mal l es

Fr m lo g te m a rages f m nthly r eason l temper t r at m y places th w rld th er ag temperature f e h lat t d nal l nd a be omputed D ff en e between th e latitudin l a ages nd th e at di id al po nts an f rm a t mpe tu a m ly map t how the effect f nt tal ty See AIR TEMPERATURE CONTINEN TALITY WEATHER AND CLIMATE [A C.]

Isentropic flow

The fl w f flu d s entrop c wh it tr py i de tic l t all po t in the flow I ent opic fl w ca b appr ched f r fluid flow*ng* th r a d ct o ve the ut d urf ce of a body Be a e the nt py of th fl d th rmodynami p p rty m lar to the e thalpy energy of a fl d the l of the tr py fixed by th tate f th flu d F a p e b t e in the b *nce of* gr ty capill rity lect ty nd mag ti m e t py i a fu ct n f two d pe d t pr p ti f r x mple the p nd t *mp* rat for a gl ph se fl id (se THERMODY AMIC PRI CI PLES)

O e f the mplest e mpl f i trop c fl w f a fl d i th gh *nozzle* wh ei the flu d i ler ted t highe loc ty by a pr e gr di t Th s fl w cl ely ppr x mated by the as-

sumptions that it is one dimensional adiabatic and frictionless (reversible)

In an actual nozzle the fluid flow is not completely isentropic because (1) the fluid shear stress at the walls is not zero thereby introducing some friction (2) a significant rate of heat transfer can occur between fluid and walls as in a rocket nozzle (3) a significant rate of mass transfer or diffusion may occur normal to the stream lines thus producing local changes of entropy in the real flow and (4) chemical reactions can occur in the flow and thus cause local change of entropy

Although the real flow in a nozzle is only approximated by an isentropic flow the latter flow can be computed quickly in comparison with the long and tedious calculations required for the real flow Hence isentropic flow is often used as a basis of comparison of the real flow with the ideal flow Thus the figure of merit for flow in a nozzle is defined by

$$\text{Nozzle efficiency} \equiv V \,/V$$

where V is the actual measured velocity issuing from the nozzle and V is a hypothetical velocity *for isentropic flow of the same fluid from the same* initial state to the same exit pressure as the real flow

The concept of isentropic flow is applied usefully *to many applications for fluid flow inside* ducts and outside of variously shaped bodies Isentropic flow is also used for predicting such flows as those of perfect gases real gases dissociating *and chemically reacting systems liquid two* phase single and multicomponent systems and plasma

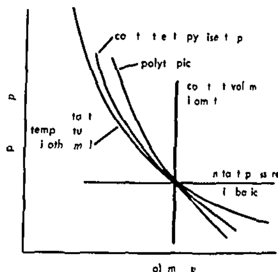
Isentropic fluid flow can be obtained in irreversi*ble processes by selecting a process in which the* local entropy could increase and then providing for sufficient heat transfer to maintain the entropy constant at all points *See* FLUID FLOW PRINCIPLES GAS DYNAMICS [J KA S I F]

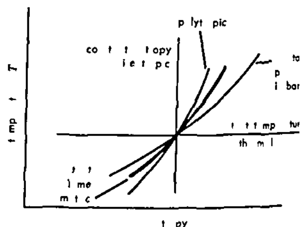
Bibliography J H Keenan *Thermodynamics* 1941 J H Keenan and J Kaye *Gas Tables* 1948

Isentropic process

A frictionless piston moving in an insulated cylinder may be used to depict this thermodynamic process Systems which are thermally insulated *from their surrounding* undergo processes without benefit of any heat transfer and such processes are referred to as adiabatic Because the isentropic process is conducted without any dissipative effect and because it receives no transferred heat it is sometimes called the reversible adiabatic process

Work done during an isentropic expansion is produced at the expense of the amount of internal energy stored in the nonflow or closed system Thus the useful expansion of a gas is accompanied by a marked decrease in temperature tangibly demonstrating the decrease of internal energy stored in the system The path is indicated on the diagram *See* THERMODYNAMIC PROCESSES





Isentropic process compared to other thermodynam p oce ses

For gases the isentropic process can be expressed as

$$P_1V_1^{\,k} = P_2V_2^{\,k} = \text{constant}$$

where P is pressure in pounds per square foot absolute V is specific volume in cubic feet per pound and k is the ratio between the specific heat at constant pressure and the specific heat at constant volume for the given gas It can be closely approximated by the values of 1 67 for monatomic gases and 1 40 for diatomic gase [J B

Isentropic surfaces

Surfaces along which the entropy and potential temperature of air are constant Potential temperature in meteorological usage is defined by the relationship

$$\theta = T\left(\frac{1000}{P}\right)^{\frac{R}{c_p}}$$

in which T is the air temperature P is atmospheric pressure expressed in millibars c_p is the specific heat of air at constant pressure and c_v is the specific heat at constant volume Since the potential temperature of an air parcel does not change if the processes acting on it are *adiabatic (no exchange*

(h t betwee the parcel and ts en ironm nt) a fa e of con tant pote t l temper tu e is al o a urface of consta t entropy Th lope of isentropic urf es in the atm pher is of th rder of 1/100 a hom A d ntag of rep e enting meteo o- gical d t on n i ent opic s faces s that here u ally l ttle a r motion thr ugh such sur tes, s ne th rmodynamic proces es in the atmos- he are approx mately adiab tic [F S]

Island faunas and floras

(I ds pro id sh p ecol g cal bounda ies in con ra t to cont nts, where the boundar es of an are inh b ted by spec es an be e tabl hed ly approximat l B th fa n s nd flora of land ge erally ha e ch racter of their wn becau e of the peculi r co d t n unde which they dev l p Th refo i e to es f the spe ies in i la d a eas ar of m r meaning t the ol gi t

Developmental conditions Development f populati n o i land in lve a con d tio f ch I t s lat n a d disjunct on attenua ti f the fl a a d fauna a d co t n ntal ers s oce ic islands

I olatio a d d sjunct on of the p pulat ns A species may be d tr buted eve al la d and co tinents. However it is u u lly s fe t a me th t an la d populat on s b ed g unit without mu h ont t w th the rest f the speci that s, i is d jun t. The s l ti n of such b eeding p pula ti m y l ad t evol t o ry ch nges r sult ng in subspec es t p es p culi r r endem t the i land

Atte uatio f fl ras and fa nas Isl nds are gener lly poo e n plant and n mal species th n comp rabl c tine tal a eas E pec ally on oc anic islands the flora and fa a ha e bee lected by th r b lity to the ce n S n e elati ly f w t rrestrial g n sms can tr el gr t d t n es oversea al fl r s d f unas ca be regarded a tu f n s by cont e t l ne

C ntin tal t us c anu isl nd Cont ental isla d ha e been co n ted to nt nt in th r geol gic p t th t the f un s d fl ra can b e plai ed on the b s f m grat n acr l nd bridges. Th pple e t sm ll fl h r i land l ke Nan ket nd V e I la d s w ll as t l rger ones u h a th Brit h I les d N w Gu n a H ev r geolog d c upport the w that th Azo es Can ry Isla d Micro e ia H wa i ad p h p th Ant lle ro n the m ddle of oce The fl as a d f as f s h o e n c i land m t th ef b e pl d a es It of occ io al d p l c the c n and subs qu nt local ps p g t n and e lut on

Endemism O a isla d sp cially h gh us d w th a variety of alt t d n l l m t zones support many pec e pec l ar or *endemic* t th m In th as of nt e t l la ds d t n t n m t be mad c rding to the ge s la ds If sep r t n oc urred d ing the Creta eou o e ly T tiary the fa a and fl a ha e a mo e oc a c chara ter tha if an i la d were separated during the later Plei t ene Th character is exp ed in the per entage f endem c pec es

To determine ndemi m all pecies f animal r pl nts on an i land m y be a igned to the f l lowi g groups

1. I troduced pecies mmigrant through human ag ncy
2. Nati e p e immigrant through no human agency
   - *a* Widespr d nati e peci fou d l ewhere s w ll as n th i land
   - *b* E dem c pecie peculiar to the i land r i l nd group not fou d el ewh r

The p ent ge and di ti cti enes f en l mi in the nati e fl a and f una ar imp rta t i d ca ti n of the degree f i lat n f an i l nd

Geographic elements I land populat ns, whether di tinct r n t are u ually related t species n nearby c ntinent In ular pec es wh ch ha e relatives the same gene al eg n re aid to be- lo g t the ame geog phic lement fau i t c or fl ri t c el ment. Thu the fl ra f Hawaii com posed f an Indo-Pac fic n Au tral an Am rican a bo eal (North rn) tr pical a Hawa ia and n introdu ed el ment

In der to obtai i formati n ab ut the r es f insular fl ra and fau a it s nece ry t have kn wl dge of all la d a ea a o nd an i land ocean c rr nt a d p e l ng wi d direct on E en l rd migr ti n r ute h uld be g en pr p r con idera ti

Si e d m c pe es and gener h e r ided n i la ds for a l ng t me the i a i n f the i land by the nc t rs may ha e tak pla e und r en tir ly d ffer nt i cumstance from tho e today Is- land may ha e changed n ize clim t r r e ta t n with re pe t to wind d e t on and currents getat and animal l fe o the ne ghbo ing c nti nents als may h b e different. Th mo e dis- t n t e a insula populati n the mo l k ly th i ts immigrat n c rred l ng ag and under d ffer nt c rcum ta ces The mo t r cent invad rs on most i l nd re t od c d o gan sm su h a rat mic roache Cau a ian m n and many weedy pla t

The relic nature of island populations I lands and i land g o ps re c nd ci e t e olut on of e d m c p pul t s al o m ny pecies onc w d ly d t b ted h e bec me lim t d to i l *nds* On the c nt ne ts th r are greater l matic flu tuat ons and m e ompet t on amo g compara t ely la g umbe f spe i s New f rm aris and pr d ap dly i d ng many hab tats On is- *land* the l m t s m r table nd equ bl th o gh th ges M ny agg ive pecies of c n t nental r g n h e ot r a hed land As a result, p m t f rm f l f ar *in efuge* on sland as el p b ot pop lat ns

Th i l ds the North Atlant su h as the A e M de a d Can ie ar *till egetated by*

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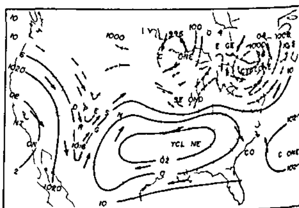
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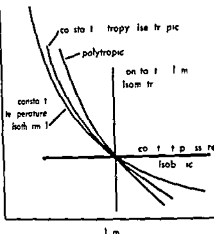
Fundamental shapes of isobars. (*After R. Abercromby, in L. P. Harrison, Meteorology, National Aeronautics Council, 1940*)

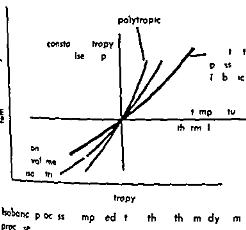
velocity about 300–800 m above the surface. (*see* AIR PRESSURE; ATMOSPHERIC HIGH; ATMOSPHERIC LOW.) The illustration presents a fictitious weather chart designed to portray the configuration of isobars generally observed. [L.P.H.]

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$$Q_P = W + U_2 - U_1 = \int_1^2 P\,dV + U_2 - U_1$$
$$= P\int_1^2 dV + U_2 - U_1 = (P_2V_2 + U_2) - (P_1V_1 + U_1)$$





Isobaric p oc ss mp ed t th th m dy m proc se

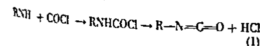
$Q \quad H - H = m\int_{1} C \, dT = m\int^{2} T \, ds$

her Q ı th tra f r ed h t at n ta t p es- F ıs w k P ı ab l te p s re H ı enthalpy U ı te l e gy V ı l m m ı mas C s p fi b at ı c ta t pres nd ıs t py S THERMODYNAM C PRINCIPLES

[J B]

Isocyanate

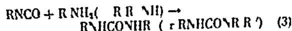
On of a gr up l eut l de ı at s of p ım ry m f rm l R—N=C=O th t are obta ed by actı w th xc ph g e nd l f hy drogen hl d Eq (1) S A ıı ε Two do bl bond b p g a ry r t syst m sel l ın the dent fi tıo of l h l and ph l u th (RNHCOOR) Eq (2) m e u a Eq (3) lkyl h l d s s l des (C_6H NHCOR) Eq (4) d b yl c a ds s m d s (RNHCOR) Eq (5)



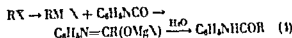
$$RNH + COCl \rightarrow RNHCOCl \rightarrow R{-}N{=}C{=}O + HCl \quad (1)$$



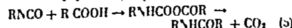
$$RNCO + R\,OH \rightarrow RNHCOOR \quad (2)$$



$$RNCO + R\,NH_2 (\;R\,R\;NH) \rightarrow RNHCONHR \;(\;r\;RNHCONR\,R\;) \quad (3)$$

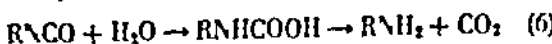


$$RX \rightarrow RMgX + C_6H_5NCO \rightarrow C_6H_5N{=}CR(OMgX) \xrightarrow{H_2O} C_6H_5NHCOR \quad (4)$$



$$RNCO + R\,COOH \rightarrow RNHCOOCOR \rightarrow RNHCOR + CO_2 \quad (5)$$

Isocya tes hydr lyze ın aır to the un table



$$RNCO + H_2O \rightarrow RNHCOOH \rightarrow RNH_2 + CO_2 \quad (6)$$

rbamıc acıd (RNHCOOH) which revert t the or gınal amı es l y lo f ca bon d xide Fq (6) Unhydr lyzed ı ocy nat the react with th amine t gı e a ymmetrı l urea RNHCONHR N r mally an ımpo ta t reactı n nly be u e the nuı s nce mu t be a ıded co troll d hydr ly ı of free ı ocy nate group t liberate carbo d xide ıs the b ı f o e type f f med plastic *S e* POLY URETHA E RESIN

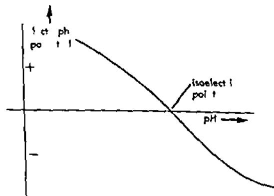
To a oıd hydroly ıs by atm pheric m ı ture socyanates a e best k pt ın se led glas c nt ı er

Repl cement f xygen by ulf r a ın ısothıo- cyanates red ces the ctivity c n ıd ably

[L B C.]

Isoelectric point

The pH al e of the d sp rs n med m of a col lo d l u pen n t wh ch the coll ıd l particle d n t m e n n elect ı fi ld th t ı the partı les ar el ctr ph r tıc lly ı ert The ıso lectric poı t ıs fte empl yed t ha a t ıze llo dal m te l u h a th prot ı However r nge of l es s ı ally neces ry sı ce the ı lectric poı t v r d te tably w th (1) the ıze f th par tı les (2) the pur ty and (3) the co c ntration of ıo s p e nt ther than hyd ogen ıon



G ph how g th l ct c po t

If the pH l e of an ext n c ol (tab lıty at t b t d p ım ıly to ele t ı al ha ge) ı djusted tow d th ı le t po t coagul tı n w ll occur at n ar th o l ctr c point I t ınsıc sol (ta b l ty tt b ted pr ma ıly to ol at) may be ar rı d to th elect c p nt with ut co gulat on but h l will be ın a regı n f mın mum sta b l ty s that m n mum c n e tr t n f d l t

laurel forests similar to those that disappeared from the Mediterranean as living forms long before the glacial epoch and are now found in its Tertiary fossil bed. The unique mammal life of Tasmania, the dragon trees of Socotra, and the silverswords and tree plantains of Hawaii are other examples of ancient forms of life surviving in the isolation of islands. *See* EVOLUTION, ORGANIC; POPULATION DISPERSAL. [K.L.E.]

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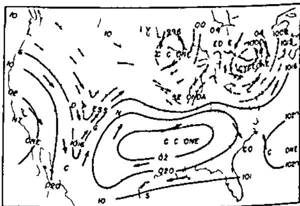
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$CH_3—CH_2—CH—C—S—CoA \xrightarrow{-2H}$
(CH under the first CH; =O on the C)

Methylb t ryl CoA

$CH_3—CH=C—C—S—CoA \xrightarrow{H_2O}$
(CH_3 under the second C; =O on the next C)

T lyl CoA

$CH_3—CH—CH—C—S—CoA \xrightarrow{DPN}$
(OH under the first CH; CH under the second CH; =O on the C)

α M thyl β h dr ybutyryl CoA

$CH_3—C—CH—C—S—CoA \xrightarrow{C A}$
(=O on the first C; CH under the CH; =O on the second C)

M th l et cetyl CoA

$CH_3—C—S—CoA + CH_3—CH_2—C—S—CoA$
(O on each C)

Acetyl CoA Prop o yl CoA

[E A AD]

Isomerism molecular

Th t rm m i m was t od ed by J J Be e h s f d ffe t chem al c mp u d ha ng th ame el m tary p e tage c mp sit on that th m rel tive p op rt ns f onst t e t le- m t Th p *b l ty th t th* s me lement ry t mpo t n n d te two m e b t n es som de s f m ga stru t e theo y whi h req es ly th t th len e n mbe of e th l m t (rb 4 yge 2 hyd ogen 1) be f ll t fied Th *s the ide* tity of ny g en comp und i fu t f the a g m t orde f) kag of th ompo e t l ments

Chain isomerism Am ng th alk e C_nH isomer *m res lt* f m th p ib l ty of l k g th sam number f rb n tom to pr d e the a straight h i br hed cha s f r mple C H repre ts b t CH CH- $CH CH_3$, d ob ta e, CH CH(CH) A the numb f arbon ne the mb r f m m ses C H r p e t CH CH CH_2- $CH CH_3$ CH CH CH(CH) a d C(CH) Ch isom r th d ff f m ch th r by virtue f po es ing d ff ent b k let n

Position isomerism Th p ti f l m t (l m t) th th n c b n nd hyd ge h h tak s the pl ce f on m hyd og s m gr t e t isome st tu Th *n mb r* of su h m d t rm ed by th mb f d ff nt typ f hyd og a gi e hyd a b Thu m m l le of m th n eth d o- pe t e, ll th h d gen t m a qu l nt (m b t t ted some re p bl d all d n t es f form l C_nH Z r d nt l) b t propane, but a d i b tan h ha tw d f f ent type of hyd g and e pabl f p o- ?nd ng t d ff t m b t tuted d at

C_nH Z (for e mple CH CH CH_2Z and CH_3 CHZCH)

If m re than on hydrog n atom i replac d by toms f one ul tit ent lement m re po it n i omer a e po ibl f e en etha e may pro- ide the e Th principle h wever remains the ame the n mb er f d ff rent type f hyd gen i a gi en m no l tit ted alkan determ ne how many i om r c d ub t tuted isomers ar p s- ble Thu C-H ZX (where Z and X may be the same or d ffer nt eleme t) r pres nts CH CHZX nd CH ZCH X a l C H ZX repres ts CH CH CHZX CH CHXCH Z, CH_3CHZCH_2X CH_2- XCH CH Z and CH CZXCH the e nd nd th rd bei g id nti l if Z and X represent the ame eleme t

In un aturated mpound (s mple alke es and alkyne) the n mb r of un que l cati n for the d uble o tr ple bond determ nes the n mb er f po tio isomers Thus a f ur-carl alkene (alkyne) i th imple t sy t m f r wh ch po it nal someri m is p ble CH CH CH=CH_2 nd CH CH C≡CH or CH CH=CHCH *and* CH_3 C≡CCH

In symm trical ycl c sy tem (cycl alkanes d be ene) all hyd oge a e eq ale t and o a with eth e at le t tw ul t tuents mu t b pr e t f the exi te ce of po ti nal isom r The numbe of h i m s depend on th ze f the ng whe the numb f ub titu nts (fo ex mple Z a d CH) is lim ted to tw Thu there are tw d ub t tuted cycl pr p nes (1 1 a d 1 2) three d ub t tuted c cl but nes and *cyclo-* pe t ne (1 1 1- a d 1 3-) and f r d si b ti tuted cy lohexan (1 1 1 2 1 3- and 1 4-) The at re of the be n r ng l mits d sub ti tuted be z es to th ee 1,2 (th) 1 3- (m ta) a d 1 4- (pa) Wh r the *e are th* ee denti al s b t tu nt C_6H Z th ee po t o al i me s are p ble (1,2 3- 1 2 4- a d 1 3 5-) b t f C_6H Z X th e are fi (1 Z- 2 Z 3-X 1 Z- 2 Z 4-X 1 Z- 3-Z 2 X 1 Z- 3-Z 5-X 1 Z- 4-Z- 2 X) A *m thod f r d* term n g the ab o- lute po t n f h s b t t ents i b n ne de- pe d up n th *per me t l* p od ct on of p t o l some f m a g e d ub t tut d be ze e (Ko ner m th d)

Cy l p r Cy l butane Cy loh xan Benz n

Wh *cy l* sy tem i n t symm tr l (cy lo- lk e h t cycl c mp d bi d p ly ycl *t hydr* rb p e es mo e th n o typ f hyd ge t m d h n e p ti al i mer m i p bl w th but o b t t e t wh eas p ly sub t t t l ad t a g t m lt pl ty of p t nal ome tha ymm t i l y l *y t m*

ing agent will cau e coagulation Likev i e vi co ity changes often reach a minimum at or near the i oelectric point *See* COLLOID ELECTROPHORESIS ION PERMEABLE MEMBRANE PROTEIN [W O M]

Isoelectronic sequence

A term u ed in pectro copy to de ignate the et of spectra produced by different chemical elements ionized in uch a way that their atoms or ions con tain the ame number of electron The following equence i an example

De ignation of pec trum	CaI	ScII	TiIII	VIV	CrV	MnVI
Emitting atom or ion	Ca	Sc^{+}	Ti^{++}	V^{+++}	Cr^{++++}	Mn^{+++++}
Atomic num ber Z	20	21	22	23	24	25

Since the neutral atom of the e element each con tain Z electron removal of one electron from candium two from titanium and o forth yields a erie of ions all of which have 20 electron Their spectra are therefore qualitatively imilar but the pectral terms (energy level) increa e approxi mately in proportion to the quare of the core charge ju t a they depend on Z in the one-elec tron equence H He Be and o forth (*see* ATOMIC STRUCTURE AND SPECTRA) A a re ult the ucce ive pectra hift progre ively toward horter wavelength oon reaching the vacuum ul traviolet region I oelectronic equence are u eful in predicting unknown pectra of ion belonging to a equence in which other pectra are known

[F A J]

Isoetales

A monotypic order of the plant ul phylum Lycop ida containing only one genu *Isoetes* The e plants are called quillw rts becau e in all 64 pe-

I oet s (a) E t e pla t (b) Long t d nal sect o f l f bas (c) Face ew of ve tral s face of l f ba e (From A J Eames E W S H a d K S W/ Bot y P c ple a d P oblem 5th ed McG aw-H ll 1955)

cies the leave are long and narrow with a poon like ba e pirally arranged upon an underground cormlike tructure *See* STEM (BOTANY) Mo t pe cie are emiaquatic although a few are terrestrial They are confined to the c oler regi n of the world

Morphologi t differ in their opini n regarding the relation hip of the gr up They are l ke the Selaginellale in having ligule two kind of pore (hetero porou) and in producing tw kind of gametophyte They are different fr m the other Lycop ida in having multiciliate perm in lacking a u pen or (a chain of cell which erve to put the embryo in a favorable p o iti n in relati n to it food upply) and in p o e ing a econdary meri tem which devel p ome econdary ti ue (*see* MERISTEM LATERAL) The pre ence of a pe cial root producing regi on which devel p new di chotomou (forked) root each year together with their anatomy ugge ts a cl e relation hip with the f il Lycop ida e pecially the genu *Pleuromeia* The phyl genetic connecti n between *Pleur meia* and *Isoetes* i accepted by many b tani t and for thi rea on the familie Pleur meiaceae and I o etaceae are often included in the I oetales *See* PALEOBOTANY PLEUROMEIALE TRACHEOPHYTA

[P A V]

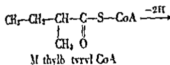
Bibliography *See* LYCOP IDA

Isoleucine

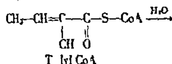
An amino acid c n idered e ential f r normal growth of animal The amino aci l are character ized phy ically by the following (1) the pK or the di ociation con tant of the vari u titratable group (2) the i electric point or pH at which a dipolar ion d e not migrate in an electri fi ld (3) the p ti al r tati n r the r tati n imparted to a beam of plane-p larized light (frequentl the D line of the odium spectrum) pa ing thr igh 1 decimeter of a lution of 100 gram in 100 ml (4) olubility *See* EQUILIBRIUM IONIC I OELEC TRIC POINT OPTICAL ACTIVITY SPECTROPHOTOMET RIC ANALY I

The bi ynthe i f i leucine ccurs wh n pyru ate and α ketobutyrate react to f rm α-aceto-α hydr xybutyrate which underg e rearrangement and red ti n to α β dihydr x β methyl al rate Dehydrati n t the α keto aci l and tran aminati n comp lete the b ynthe i (*see* AMI O ACID) M t r ll f the enzym c nc rned al cat lyz the anal go rea ti n i valine bi ynthe i *See* VALINE

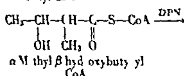
During metabolic degra lati n the fr t t p are l aminati n and oxi lati le arboxyl ti n f rm ing α m thyllbutyryl oenz m A (α m thyllbutyryl C A) Th f ll wing quenc tak pla



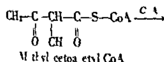
M thylb tyryl CoA



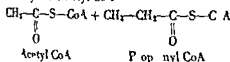
T lyl CoA



α M thyl β hyd oxybuty yl CoA



M thyl cetoa etyl CoA



Acetyl CoA P op nyl CoA

[E A AD]

Isomerism molecular

The t m som r m was t d ced by J J Berzelıu f r diff nt ch mı al omp unds h ng the sa e el me t ry p ce tage mp ıt on th t ı th me relat e p p tı n f c n tıt nt ele m ts The po b l ty that th am el m ntary compo t a den t two r m ubstances som r d rı f m organ t uctu theory whı h eq es only th t the ale ce n mb of e h l m nt (k 4 oxyg hyd g n 1) be f lly t fied Thu the ıde t ty of y g en compo d f nct f the a r g m nt r d fl ka l th mpo t lements

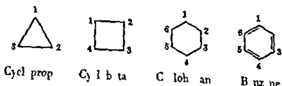
Chain isomerism Am g the alk ne C_nH ısom m results from the p s b l ty f lı k ng the same umbe f c bon t m t p oduce e ther a tra ght ch br ch d h ın f ample C_4H pr sent b tan CH CH_2 CH CH nd sobuta CH CH(CH) A th mbe f bon n r es th be of so- me ın ses C H repr nt (H CH CH- CH CH CH_3CH CH(CH) d ((CH) Ch m r the d ffer fr m e h othe by utu f posses g diff nt ca b n kel to

Pos tıon ısomerism The po ıt n f n l me t (l m t) tl r th n a bon d hydr g n wh h take th pl e of e o m hyd e may gı e e t ı me t ctu e Th n mbe f u h somers det m ed by th numb of d ff rent types of h d g g n hyd o b n Th s ın m lec l f m tha e, th ne nd neo- m n bstıtuted m r a p bl and all de a es of form la C_nH Z a e d nt al) b t prop b t ne d ı but n a h ha e tw d f ferent types f hyd g n nd e pabl f p o- d d t s C_nH 7 (f r example CH CH CH_2Z and CH_3 CH7CH)

If m re than one hydr gen at m ı replaced l y atoms of o e ıl t tuent element more p ıtı n ısomer are po ıble and e en etl ane may pro- vide tl e e The prıncıple how er r main tl e me the nu nl er of different type f hydrogen ın a g ven m n ul tıt ıted lkan determ n s how m ny ı m rıc dı ub tıtuted ısomers are pos- s ble Thus C H ZX (where Z and X may l the ame or d fferent element) represents CH_3CHZX and CH 7CH X and C_3H ZX rej resent CH_3 CH CHZX CH CHXCH Z, CH CH7CH_2X CH- XCH CH Z, and CH CZXCH the econd a d thır l be g ıdentıcal ıf Z and X represe t the me element

In unsatu ated comp unds (sımple alk ne and alkynes) the number of un que l catı n for the double r trıple l nd determınes the numl er f po ıtı n ısome Thus a four-ca bon alkene (r alkyne) ı the s mpl t y tem for which po ıtı nal ı m r m ı po ıble CH_3CH CH=CH_2 a d CH CH C≡ CH or CH_3CH=CHCH_3 a d CH_3 C≡CCH_3

In ymm t ıcal cy lı y t m (cycl alkane a d b nzene) all hyd ogens are eq alent and o s w th eth ne t le t two ub tıtuent m t be p es nt fo the exı tence of p tı al ı m r The number of s ch som r d pend o the ıze f the rı g when th numb r of sub t tı ents (f r xampl Z nd CH) ı l m ted t two Thu ther re tw d ubst tute l yclopropanes (1 1 and 1 2) thre d b tıtut d cy l butane a d cy lo- p ntane (1 1 1 2 and 1 3-) and f r dı ul tı t ted yclohexa e (1 1 1 2 1 3- a d 1 4-) The n tur f the l enz ne r ng lımıts dı ub t t ted b n e es t three 1,2 (tho) 1 3- (*met*) and 1 4- (para) Wher th r three ıdentıc l bst t ı nt C_6H Z three p ıt nal ısomer are p s bl (1 2 3- 1,2 4- a d 1 3 5-) b t f r C_6H Z X th e are fi (1 Z 2 Z- 3-X 1 Z 2 Z- 4-X 1 Z- 3 Z 2 X 1 Z- 3-Z 5-X 1 Z- 4-Z 2 X) A meth d for d term n g th ab o- l te p s t o of su h b t t ents ı b n ne de- p ds up n the e pe ım ntal p oduct n f p ı t on l ısom fr m a g en d s b t t t d ben (Ko n s meth d)



Cycl prop Cy l b ta C loh an B nz ne

Wh r y l sy t m n t ymmetr cal (cyclo- lk e het orycl c mp und b a d poly ycl y tems s h d c l n a d n phth l n) th p r e t b d ca b n pos e es m th n e typ of hyd ogen t m nd he p ıt n l ı om r sm p bl w th b t e ub t t t wh e s poly b t t t l ds t g e t r mult pl ıty of p s t al me th n n ymm tr c l y l yst m

ing agent will cause coagulation Likewise viscosity changes often reach a minimum at or near the *isoelectric point* See COLLOID ELECTROPHORESIS ION PERMEABLE MEMBRANE PROTEIN [W O M]

Isoelectronic sequence

A term used in spectroscopy to designate the set of spectra produced by different chemical elements ionized in such a way that their atoms or ions contain the same number of electrons The following sequence is an example

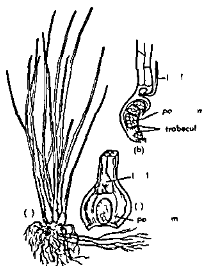
Designation of spectrum	CaI	ScII	TiIII	VIV	CrV	MnVI
Emitting atom or ion	Ca	Sc^{+}	Ti^{++}	V^{+++}	Cr^{++++}	Mn^{+++++}
Atomic number Z	20	21	22	23	24	25

Since the neutral atoms of these elements each contain Z electrons removal of one electron from scandium two from titanium and so forth yields a series of ions all of which have 20 electrons Their spectra are therefore qualitatively similar but the spectral terms (energy levels) increase approximately in proportion to the square of the core charge just as they depend on Z in the one electron sequence H He Be and so forth (*see* ATOMIC STRUCTURE AND SPECTRA) As a result the successive spectra shift progressively toward shorter wavelength soon reaching the vacuum ultraviolet region Isoelectronic sequences are useful in predicting unknown spectra of ions belonging to a sequence in which other spectra are known

[F A J]

Isoetales

A monotypic order of the plant subphylum Lycopsida containing only one genus *Isoetes* These plants are called quillworts because in all 64 species the leaves are long and narrow with a spoonlike base spirally arranged upon an underground cormlike structure *See* STEM (BOTANY) Most species are emiaquatic although a few are terrestrial. They are confined to the cooler regions of the world

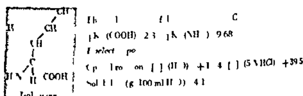


Isoetes (a) Entire plant (b) Longitudinal section of leaf base (c) Face view of ventral surface of leaf base (From A J Eames and E W Sinnott and K S Wilson Botany Principles and Problems 5th ed McGraw-Hill 1955)

Morphologists differ in their opinions regarding the relationship of the group They are like the Selaginellales in having ligule two kinds of spores (heterosporous) and in producing two kinds of gametophytes They are different from the other Lycopsida in having multiciliate sperm in lacking a suspensor (a chain of cells which serve to put the embryo in a favorable position in relation to its food supply) and in possessing a secondary meristem which develops some secondary tissue (*see* MERISTEM LATERAL) The presence of a special root producing region which develops new dichotomous (forked) roots each year together with their anatomy suggests a close relationship with the fossil Lycopsida especially the genus *Pleuromeia* The phylogenetic connection between *Pleuromeia* and *Isoetes* is accepted by many botanists and for this reason the families Pleuromeiaceae and Isoetaceae are often included in the Isoetales *See* PALEOBOTANY PLEUROMEIALES TRACHEOPHYTA [P A V]

Bibliography *See* LYCOPSIDA

Isoleucine



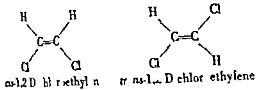
An amino acid considered essential for normal growth of animals The amino acids are characterized physically by the following (1) the pK_1 or the dissociation constant of the various titratable groups (2) the isoelectric point or pH at which a dipolar ion does not migrate in an electric field (3) the optical rotation or the rotation imparted to a beam of plane polarized light (frequently the D line of the sodium spectrum) passing through 1 decimeter of a solution of 100 grams in 100 ml (4) solubility *See* EQUILIBRIUM IONIC ISOELECTRIC POINT OPTICAL ACTIVITY SPECTROPHOTOMETRIC ANALYSIS

The biosynthesis of isoleucine occurs when pyruvate and α ketobutyrate react to form α aceto α hydroxybutyrate which undergoes rearrangement and reduction to α β dihydroxy β methylvalerate Dehydration to the α keto acid and transamination complete the biosynthesis (*see* AMINO ACIDS) Most or all of the enzymes concerned also catalyze the analogous reactions in valine biosynthesis *See* VALINE

During metabolic degradation the first steps are deamination and oxidative decarboxylation forming α methylbutyryl coenzyme A (α methylbutyryl CoA) The following sequence takes place

plans ring serv s a a ref re ce po nt in the m lecule and uch m r a e alled geometrical isom rs

Cis t n s isomerism In any alke ie system where th d blv b nded carb n each c rry two different t m or gro ps is-tr ns i omers re po bl that i tw s m lar at ms r g oups may l e n th same d (c) r oppos t ides (tr ns) of a plane b secting the alken e carbon nd perpe di ular t the pl n f th alk n c ystem f e ample

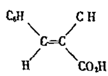


cis-1,2 D hl roethyl n *tr ns*-1,2 D chlor ethylene

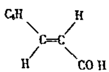
Th r g d ty of th d ble bond prev ts free rot tion, and th s th tw geomet i ally diffe ent i omers con t tute d tinct e t tie wh h cannot be interco rted ith ut the expend t re f uffic ent energy t de troy th es t al h r cter of the d ble bond

S h i, m s w ll d ff both i hem c l proper ties and in e e gy o t nt the tr n m r i u ll th m r t ble therm dy amically E i den s pp rt of the l tter t teme t s fo nd in th mp ti n of the q libri m mi t e whi h co t n m of th t ns somer wh never ither form i bjected t cond t ns perm tting nte (h gh temp ratures r at ly i i l i g ph toch m al f e d cal nic mecha n m)

I des g ting part l i me a ci r tran th proper ref ence p nts m st be u ed pref bly h f the lk n e bo hould a ry denti l at m gr p o l ld carry atom gr p so cl ly elat d th t no amb gu ty i pos bl (B d Cl CO H a d CO R r CO H a d CN) Th th α-phe yl nam c id

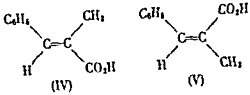


i d ri ed f mo din ry (tra s) c m c d

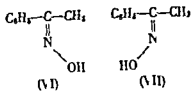


h err neo l b c ll d t n b u of it derm ti n A t lly th c des gn t t in th ly g o p c mm n t both alk n c c r bo s th ph yl gr up

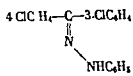
Syn-anti is m rism Ge m t l om th t d t c rry d t l o clo ely el ted t ms o gr ps th alk n c e bo c t be n med n amb gu ly u g c s-t a me clatu F r ampl th m thyl m d (IV) a d (V)



and the oximes of acetophenone



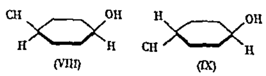
cann t p operly be called trans or cis Therefore the te ms anti (n opposite sides) and syn (on the me side) are used The larger (or chemically more reacti e) group is taken as the reference po nt (C_6H_5) and the functi nal group CO_2H i (IV) and (V) OH in (VI) and (VII) is said t be anti (IV) a d (VI) or yn (V) and (VII) to it Thu (IV) is anti α methylcinnamic ac d (VI) is ant acetophenoneox me and (V) and (VII) are the orr spond ng yn i m rs Syn a ti is merism will be enc u ter d thro ghout imin chemi try in s far a the d ubly bonded ca bon arri two dif fe ent ubst t ent but it may be nece sary t pec ify to wh h s b tituent the nitrogen substituent is syn o anti thus n



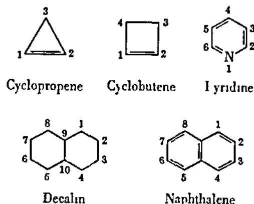
the phenylam n group s a ti to the 4-chloroph nyl and yn to the 3- hlo phenyl Sim lar sit ations may btain n yn anti is me ism mo g alken c mpou d

R g isom rism If subst tuent are att hed to alk n c a b ns which a e part of cyclic system the ng of wh h co ta ns few r than e ght mem b rs f xample, 1 2-dichlorocyclohex e bo d l ngth d b d angles p e t the ex tence of the t s stru tu In am ng ch subst nces it n t n ce a y t be e pli it, d th cis de igna tio s t mployed

H w er ycl c stru tu s admit of geom trical ome m in anoth r en bst t ents m y be pl ced n the am (is) or ppos te (trans) ide f the pl e (a b t ily) defined by the t ms of th i g Th the e a e the geometrical me 4-methyl yclohe an 1 (VIII) and *t* ns 4-meth ylcy l he a l (IX)



Thus there are two monosubstituted cyclopropenes and cyclobutenes (1 Z- and 3 Z) three monosub stituted pyridines (2 Z- 3 Z and 4-Z) three monosubstituted decalins (1 Z 2 Z and 9 Z) and two monosubstituted naphthalenes (1 Z and 2 Z-)



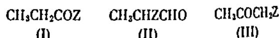
Naphthalene illustrates the effect of polysubstitution on positional isomerism in unsymmetrical cyclic system In the parent hydrocarbon positions 1 4 5 and 8 are equivalent and are designated α positions 2 3 6 and 7 are designated β The introduction of a substituent Z in either an α or β position destroys the equivalence of all other positions thus there are no fewer than 10 positional isomers for a naphthalene bearing two identical substituents Z (1 2 1 3- 1 4- 1 5 1 6 1 7 1 8 2 3 2 6 and 2 7) Where the two substituents Z and X are not identical four of the listed isomers each provide a pair since an interchange of substituents in the 1 2 1 3 1 6 and 1 7 structures each provides a new isomer making 14 in all Higher order substitution enormously increases the number of positional isomers but in naphthalene as well as in the other types of unsymmetrical cyclic systems the principle governing the total number of positional isomers remains the same It is determined by the number of positionally different hydrogens which may be replaced by other atoms or groups of atoms

Functional group isomerism The presence of multiple bonds or of atoms other than carbon and hydrogen (for example oxygen nitrogen) in an organic compound may give rise to isomers whose functional groups or reactive centers exhibit chemically distinguishable properties Thus the formula C_4H_6 may represent 1 butyne 2 butyne (positional isomers) methylallene (CH CH=C=CH_2) 1 3 butadiene (CH =CHCH=CH) 1 or 3 methylcyclopropene (positional isomers) r methylene cyclopropane In the same manner the mono alkenes are isomeric with cycloalkanes and di alkenes with alkynes bicycloalkanes and spiranes

The introduction of oxygen to give compounds of the molecular *formula* C_3H O may produce alcohols CH_3CH_2CH OH and $CH_3CHOHCH_3$ (positional isomers) or an ether CH CH_3OCH_3 When the carbon content is greater positionally isomeric ethers are possible as well Likewise the introduction of nitrogen may lead to functional group isomers thus C_3H N represents *n* and isopropylamine CH_3CH CH_2NH_2 or (CH_3) $CHNH_2$ chain isomers ethylmethylamine CH_3 CH $NHCH_3$ or trimethylamine $(CH_3)_3N$ These three amines are functionally different and are classed as primary secondary and tertiary respectively

Where the molecular formula is C H O further possibilities for functional group isomers obtain Thus C_3H_6O represents an aldehyde CH_3-CH CHO a ketone CH_3COCH_3 two cyclic ethers CH_3CHCH (O) and CH CH_2CH_2 (O) and an unsaturated alcohol CH =$CHCH_2OH$ Likewise C_3H N represents three aldimines CH_3CH CH=NH CH_3 CH=NCH_3 and CH-=NCH_2CH_3 a ketimine CH_3C=$NHCH_3$ azetidine (CH $)_3NH$ two ethyleneimines $(CH_2)_2NCH_3$ and [CH $CH(CH_3)$] NH and two unsaturated amines CH-=CHCH NH and CH =$CHNHCH_3$

Where two or more heteroatoms (atoms other than carbon and hydrogen) are present the possibilities for functional group isomerism may be illustrated by the following structures wherein Z represents OH *O* alkyl halogen or NH



CH_3CH_2COZ	$CH_3CHZCHO$	CH_3COCH_2Z
(I)	(II)	(III)

Where Z is OH (I) represents an acid (II) a hydroxyaldehyde and (III) a hydroxyketone where Z is *O* alkyl (I) is an ester (II) an alkoxy aldehyde (ether aldehyde) and (III) an alkoxyketone where Z is halogen (I) is an acid halide (II) a haloaldehyde and (III) a haloketone and where Z is NH_2 (I) is an amide (II) an amino aldehyde and (III) an aminoketone Furthermore within each series regroupings of the constituent atoms are possible for example where Z is OH the atoms of (I) may be rearranged to represent various ethylene and propylene oxides (three and four membered cyclic ethers) with a hydroxyl substituent or the OH group may be broken up to form methoxyacetaldehyde CH OCH CHO or the esters methyl acetate CH_3OCOCH and ethyl formate CH_3CH OCHO

Geometrical isomerism In the molecules of these isomers the atoms are attached to each other in the same order but with different spatial or geometrical orientation The explicit geometry im p ed up n a molecule by the pre ence of a double bond between carbon atoms or between carbon and nitrogen or by the presence of a ring system (which for convenience may be considered planar however see CONFORMATIONAL ANALYSIS) make possible the existence of these isomers Thus two atoms or groups of atoms attached to each of two different carbons may be relatively closer to or farther from each other depending on the respective directions of the bonds from the carbons to which they are att d The rigid d ul le l nd r

i lectr s, y r) r j os tron electr n pair
n y be m tted from th atom i uch trans t ons
The half l fe of an i m r and the o der of the
muh po! radiat o em tted a e intimat ly c n
necteu w h the d flerence betwe n the sp n or an
gula m m t m f th nucleus in the i omeric
state a d the p n of the energy l l to wh ch it
dee Th half l fe al o depend upon the tran
no e gy b t f r a g e energy the half life
will be several d rs of magnitude long r for e ch
add u l un t of p1 change

Se MULTIPOLE RADIATIO RADIOACTIVITY

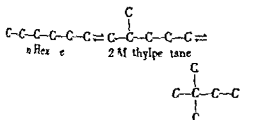
[D E A]

Bibliog aphy S Flu gge (ed) *Handbuch de Phy k*, v l 4 1957 K S gbahn (ed) *B ta a d Gamma R y Spect scopy* 1955

Isomerization

R arrang m t of the atoms within hydr carbon mo ec l s. Isom zat n p oc es of practical gnifi a e in pet leum hemi try are (1) mi gr t l alkyl group (2) h ft of a ngle-carbon bo d in phth ne and (3) double-bond h ft in l fins.

Migration of alkyl groups An ex mple of alkyl gr p mi grat n (k let l i mer zat on) s



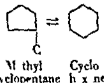
Isom izat t m e h hly b a ched c nfigu a t s h mme c l imp rt n e s nce it esults in (1) imp o ement in c mbu t on quality n the i t m bile ngin as me s d by tane n mbe and (2) a ed ch mical r a ti ty be u ter b ry c rbo t m ult. Th *unleaded moto* m th d octane numb f the abo h an i o- ers ar *6 0 3.5* and 93 4 respect ely N rmal butane c n e ted to i but ne (wh ch has te tiary a bon tom) t *att* *h* mical rea t ty th l fins lkyl t r t whe *n*-b t n is inert.

Isom rizat of p ffi s s a ever ible fi t rder r a ti n l m t d by th rmodynam q l b- rium wh ch f rs i ed I ran h ng at lowe temp t e U des abl ck ng ea ti n l ad ing to talyst de t t n o u at h ghe tem per ures. Th y a e t lled by dd g a c a k ing upp esso s h as hyd gen

C n ers n f n rm l buta e to sob ta *e is* th mm c l *f i om* izatio U ually t carried ut i th r l q d r po ph o e m um hl id atalv t pr moted w th h d o- gen hl d In th v p r pha e p oces (250- 330 F) th l *m* um hl r d *It s* pp t d on b ux e. I th l qu d ph proce s (180 F) t i di ol ed in molten ant m ny trichloride or used in the form f a *liquid compl x with hydro- c rbon* A sec nd type f ataly t for apor pha i om rization (300–850 F) is a n l l metal u u ally platinum upp rted on a carr er This may l e alumina with hal d added to pro de an acidi sur face *All the pr cesses are select e* (95–98% to *isobutane*) *App oximately* 60 f the n l ut ne feed i con erted per pas to i l itane in the liquid pha e pr ce

I pentane a h gh-o tane comp nent u ed i aviat n ga li e is made ommercially l y omeri zat on f n pentane Pet leum naphthas c nt in ng fi e and i carbon hydrocarbon also *re i omer* ized commercially for imp ment n m t r f el ctane numbers N ble-metal catalyst is normally u ed with higher m lecul r weight fe d Isomeriza t n of p raffins bo s x ca bon toms i of le s mportance a nc octane imp em nt i limited by p edominance f m nomethyl b anch ng at quilib- r um. Skeletal i omerization is an important sec ondary r acti n in catal t c cracking and cat lytic reform ng. Aromatic *and ol fin undergo skeletal* is merizat n as do pa aff ns

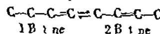
Single carbon bond shift This p *oce s, in t e* ca of aphth es i illust ated l y the reacti n



M thyl Cyclo
cyclopentane h x ne

Cycl hexan nd meth l ycl hexane *ha e been* p odu ed c mm rc ally by liquid pha e i m za *t on* of the fi e-ca bo rt g is mer o r al minum chlo ide–hydrocarbon-complex catalyst prom ted *by hydrogen chl ride Con e ion per pass i higl* sel ti ity e ell nt a d *reaction* cond ti n m ld (190 F) Cycl hexane s *raw mate ial fo m k ing nyl n* nd t may b dehydr ge at d t l en zene Methyl ycl hexane has been u ed *to m k synth tic nit* at n g ade t l e e

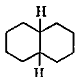
Shift of a double bond This pro s is f lly applied wh n a pecifi ol fi i needed for chem cal ynthes f ex mpl



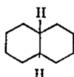
Do bl b nd h ft oc u s lect ely e d c ataly ts at *temperatu es bel w 450 F* Howev r th pr port n und go ng keletal om rizat n in rea e t mp r tu e is n a ed u til t tem p rat es in the rang 600–950 F equil brium app o ch d at fai ly h gh spa elo itie *Eq il b- ri m* f v m eme t of do ble bo d t the *mo e* stable int l p t on (85% 2 but ne at 400 F) a d cta e imp ment a c mp n es thi sh ft how e the n ea n rm lly is i ffi *ient t j st fy the* t f p e ng th mally cr k d g s l nes l ly f th s p p Th typ f om izat n o u a c nd ry e t on i th t lyt c k i g nd c t l t c p lymerizat n

The geometrical designations are referred to the principal (lowest numbered) substituent in the present instance the hydroxyl

Bicyclo[x y 0]alkanes (for example bicyclo [4 4 0]decane decalin) may have either a cis or trans ring junction (if the rings are sufficiently large)

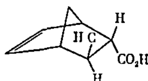


ci Decalin

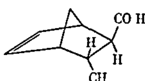


t ns Decalin

However in bicyclo[x y z]alkanes notably Diels Alder adducts of cyclopentadiene with substituted alkenes only cis ring junction is possible and the designations endo and exo are used respectively to locate substituents trans (anti) or cis (syn) to a bridge Thus in (X) the carboxyl is endo and the methyl exo whereas in (XI) they are reversed



(X)



(XI)

Two further geometrical isomers are possible in this system one in which both sub tituents are endo and the other in which both are exo

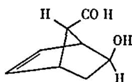
The terms cis and trans syn and anti al o find application in the bicyclic systems Thus (XII) and (XIII) and (XII) and (XIV) may be con sidered syn (XII) and anti (XIII XIV) isomeric pairs and the prefix anti may be affixed to both carboxyl and hydroxyl in naming (XV) All four are geometrical isomers *See* OPTICAL ACTIVITY STEREOCHEMISTRY TAUTOMERISM [W R V]

Bibliography H Gilman *Organic Chemistry* 2d ed vol 1 1943

Isomerism nuclear

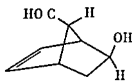
The metastability of excited states of atomic nu clei While all excited states of atomic nuclei have finite half lives isomers are defined as atoms who e nuclei exist in excited states for measurable lengths of time (*see* EXCITED STATE METASTABLE STATE) Isomeric half lives as short as 10 ec and as long as several years have been measured The total energy of the nucleus when in an iso meric state may be from a few thou and to a few million electron volts greater than the energy of the nucleus in its ground state

Nuclear isomers may decay by β ray po itron or α particle emission or by the capture of atomic electrons but most often they lose their energy by making transitions to lower energy levels or to the ground state of the same nucleus Internal conver



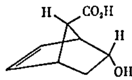
(XII)

e o 2 Hydroxyl icycl [2 2 1] 5 l epte e *syn* 7 carl o ylic acid
syn 2 Hydr xyl y lo[2 2 1] 5 l eptene *syn* 7 ca l xyl c ac d



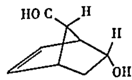
(XIII)

exo 2 Hyd oxyl i y l [2 2 1] 5 l pten *ant* 7 b yl c a id
syn 2 Hy l yb yel [2 2 1] 5 l ept ne *nt* 7 ca l xyl acil



(XIV)

end 2 Hydroxyb ycl [2 2 1] 5 l epten *syn* 7 arl oxyl acid
t 2 Hydro yl y l [2 2 1] 5 l pt *y* 7 l oxyl acid



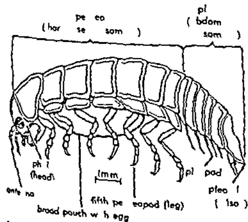
(XV)

do 2 Hyd yb cycl [2 2 1] 5 l epten *t* 7 rl oxyl c d
anti 2 Hydro yb y l [2 2 1] 5 l ptene *nti* 7 arl xyl c ac d

ally n niu t on th p-amin alicylic acid and str pt myc n H wev r iproniazid s now used a a p h c nerg z r t t eat b th mild and e ere de- p ess o s and p ych es a c ated w th evere e- pres n o eg ess ns. *Se* P YCHIC ENERGIZER P YCHOSIS Se als CHEMOTHERAPY TUBERCU LO IS. [N J C]

Isopoda

An rd r of mala o tracan crustac an wh ch are chara t ized by ha ng ceph l n r head bea ing o e p i of ma ll peds in add ti n to the a t ma d bl and ma illae The maxill peds re d rived f om the legs of th fir t po tcephalic som te wh ch lmo t c mpletely f ed with the eph l n A apa is l cki g Tl e perae n or th x, c t of seven d t nct om t s e ch b ar ing p r of p re opod the legs The fi t pa r of pe opod i n er helat a d typ c lly all pa rs f pe pod e m lar n tructu e The ple r abd m n ha i m te The fir t fi e pair f pleo al appe d ges ar f l aceous The la t p ir is mod fied t ha dened ppe dage called u opods a d th la t som t s f ed w th the t l on int a pleot l n Att ched to the inner ba e of the p re o- pods f the fem l ar platel ke app nd g s alled oost g s Pr o to egg depo iti n the o t git eal rge a d i t cle s t form a b ood p ch nt hi h th egg are d p it d L rval dev l pment o urs in th gg wh le t is in the brood pouch m rs p m Th you g hat h f m the egg int the b ood p u h fr m h ch th y m g min atu e adults lackin only the eventh p i f perei p d These a e add d du ng few po teml v ni m lt Th r o pa ental ar of the hat hed y g The ld the ry th r th y ung ec i e no r hment f m the pa e t ha b en ab nd ed The te es a e p te f rt l zat n i inte al and the mber of egg p odu ed u ally l s tha 50 The f m l th ally h te rygo nd du l b t l itl i kn wn f th g n t s of opods



L orus f m le p d (F om R J Me Th om Limno ia M m f C mp Zo l gy H rv d C lleg B ll 112(5) 363–388 1954)

Ecology Th m st familiar i op ds are the ter re t ial sow bugs or pill bug Many f the e a i mals r ll up into a c mpact ball when di turbed Land i pod are u ually f und in moi t en iron ments under d caying lea es and wood and under rocks I pods range in size from 1 mm (*Munna*) to around 20 cm (*B thynomus*) In addition to l e- ing found on land i op ds ha e been found in h t springs (*F sph eroma therm philum*) and in sul terran an fre h waters (*Caecidotea*) and ca e The majority a e marine where they range fr m the in t rtidal area t the g eat st depths of the ea Their food aries from wood (*I im oria*) and ea weed (*Lim oria* and *Idothea*) t animal fle h (*Ci ola a* and *Cymothoa*) *Ci ola a* has been kn wn to infli t small but painful wounds on swim mer *Cymothoa* and t all es are predaceou comme sal and para itic on fi h The de truct e mar ne wood bor ng isopod *Limnoria* the gribble causes annual damag e timat d at $ 000 000 t wharf p ling n the United States and one species i repo ted to att ck treated timber

Geolog c lly isopods are an an ient group rang i g from th De on an to the Rece t The genus *Cyclosphaeroma* fr m the Juras c of England i the be t k own isopod foss l and belongs to the o temp r ry fam ly Sph erom dae

Classification Th cla ificati n of the Isopoda is not tab l zed f r example the gnathiids a d a thurid are ncluded in the suborder Flabel lifera by ome in estigato nd not by othe Tl e s a ne d f r crit cal re ar h on the gener alities of th i la s ficat M t tudents di ide the opods into seven equ ale t ub rders the Oni c dea V l if ra Flabellife a Bopyr id a Gnath ode As llota and Phreatoic d a

The On s de a e the pill b g w bug and wood l ce wh h a e t r e tri l Some ha e ps udo- tr h a on ple p d nd the urop ds a e terminal *Oniscus Po cell o* and *D t* a e c mmon example

Val ife a e marin and fresh w ter specie with al el ke opods i flexed u de the pleon and c e i g the pleop d The m nd bles lack a palp Th nim ls su h s *Idothea* a d *Arct s* ar fre l vi g

The Flabell f a a ma e nd fre h w t r sp c es with the uropod exp ded lat rally w th the ple n to form a ta l fan Thes an mals re f e l ng p edaceo s c mmen al and para itic *C la a Cym th a, A thu a* nd *Lim ori* re c m mon ge

B pyr d are mar ne para t s c u ta eans The young a e m cl l ke fl bell fe n but the d lt f m le s metamo phos d int a leafl k ac nd the male i m ute with many parts redu ed E mpl a e *Bopy s* and *Io e*

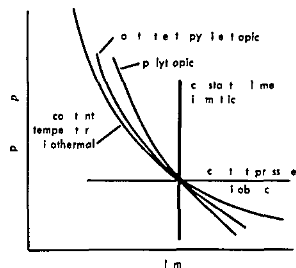
Gnath de a 10-leg d m i pa a t s f fi h with later l ur *pod Th fem l m* thparts ar t l wh le th m l mand bles a e p nce l ke and p oje t b y nd th fro t l marg n of the cephalon a in *C th*

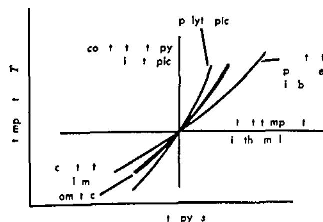
A ll ta a m ll ma e and f esh w t pe- es Th r p d e styl f rm nd t rm nal Ex

processes in part accounting for the high octane numbers of the gasolines *See* ALKYLATION AROMATIZATION CRACKING ISOMERISM MOLECULAR PETROLEUM PROCESSING [G E L]

Isometric process

A constant volume frictionless thermodynamic process in which the system is confined by mechanically rigid boundaries Because no work can be done on the surroundings by a system with rigid boundaries the heat transferred to the system equals the increase of internal energy stored in the system This increase of internal energy in





Isometr c p ocess compared t other thermody m c p ocesses

turn is a function of the specific heat and the temperature rise of the system

$$Q = U_2 - U_1 = m \int_1^2 C \, dT = m \int_1^2 T \, ds$$

where Q is the heat transferred at constant volume U is the internal energy m is the mass C is specific heat at constant volume T is the absolute temperature and s is the entropy The diagram shows that there is an increase in both the temperature and the pressure of a constant volume of gas as heat is transferred into the system *See* THERMODYNAMIC PROCESSES [J B]

Isomorphism (crystallography)

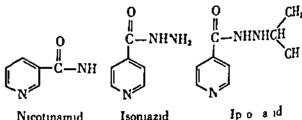
A similarity of crystalline form between sub tances of similar composition Two substances which are isomorphous have a similar chemical formula an equal or nearly equal ratio of cation to anion ra dius and comparable polarizabilities of their ions. Isomorphism is morphotropism in a narrower more precise sense (*see* MORPHOTROPISM) Similarity in the macroscopic characteristics of i omorphous crystals becomes so close that extreme precision is needed to distingui h between them

Examples of isomorphous substances are $NaNO_3$ and $CaCO_3$ $CaAl_2Si_2O_8$ and $NaAlSi_3O_8$ and $BaSO_4$ $SrSO_4$ and $PbSO_4$ Substances such as ThO_2 and LiO_2 are anti isomorphous they both ha e the calcium fluoride structure but the positions of the anions and cations are interchanged in the two structures because of the relative sizes of the ions Isomorphous substances form mixed crystals while anti isomorphous substances do not For a discussion of the chemical composition and crystal structure of isomorphous minerals *see* MINERALOGY *See also* CRYSTAL STRUCTURE [W D]

Bibliography R C. Evans *Introduction to Crystal Chemistry* 1939 A E H Tutton *Crystallography and Practical Crystal Measurement* 1911

Isonicotinic acid hydrazide

A chemical compound used as a chemotherapeutic agent for certain infectious and noninfectious di eases The observation in 1945 that the vitamin nicotinamide inhibits the growth of the bacillus which causes tuberculosis led to a search for similar activity among compounds chemically related to nicotinamide The direct outcome of this sear h has been the discovery of two drugs with outstand ng potency against the tubercle bacillus i onicotinic acid hydrazide (isoniazid) and its isopropyl e ter (iproniazid) The chemical structures of the e compounds are as follows



Isoniazid and iproniazid are highly specific in their action against the tuberculosis organi m (*Mycobacterium tuberculosis*) They ha e proved inacti e against a large number of other bacteria protozoa and viruses upon which they have been tested In the treatment of human tul erculosi iproniazid is no longer used l ecau se f t xic effects produced during its chronic administration Thi toxicity may be due to the inhil tion f monoamine oxidase an enzyme with which i oniazid d es not interfere Thus isoniazid alone enjoys wide ; read usage in the treatment of human tuberculo i u u



Fig 1 A p o f u d th t t of t m t (K f t) th sary t th l f f som term es th y t nzym s wh h d g t llu-lose th p c p l food f thes t m t G tly m g fied (F m T E S yd O E emy th T m f C s k 1935)

ı jurı u to f rest, f uit and hade trees tea bushes fi ld cr p and grass on the veldt Their d mage to truct res f man and their content ıs er us e en ı temperate regı ns In the United State this an u l l ıs e timat d at $100 000 000 *See* HYPERMASTIGIDA

Termite castes Term tes are p lymorphic. Ther are males female and three types of re-producti e f rm the monogam s winged f rms with fu ctı n l eyes the ȷ lygam u forms with wı g pad and the polyg mo s wingle forms (F g 2) A e es of intermed ates ıncl dıng fer t le o-called soldie s also occur The e may be th ee (Fig 3) t fi e types of ter le mal or fe-mal soldiers and tw types of sterile male fe m le w rke They are usu lly blind There ıs g at dı er ty of kinds nd great stru tural dif fe e c between the ca tes Interc stes also occur b tw n wo k s a d ld er Th re ıs no worker c te am ng the mor p mit ve t rmites nd nymphs take er the r duties Amo g ne highly sp cial zéd term te n ldı r ca te occurs As a r le where w rke do occur they onstit te the m st umero te n the c lony for the greater port o f the year wh re oldı rs c titute b t mall proportı n of tl e col y At ertain easons of the year ı the Un ted States all types of the ep odu tı e form occu ın ery large umbers

D ıs n of l b r The ıs a dı ıs n of labor with b th r p odu t e nd sterile form *present ın* the ol y Th ep oduct es keep the col y alı e The wo kers whı h ha e ev l ed f m the soldier a te rep r the nest nd ca e for and feed the yo ng th rep odu t f rms d tl e sold ers

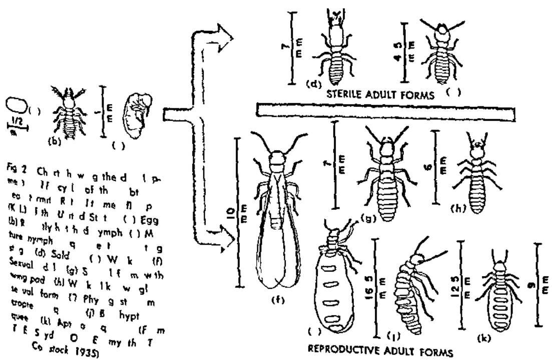


Fig 2 Ch rt h w g the d l p-me) l f cy l of th bt ea t rmit R t l t me fl p (K L) f th U n d St t ( ) Egg (b) R tly h t h d ymph ( ) M ture nymph q e t t g s g (d) Sold ( ) W k (f) Sexual d l (g) S l f m w th wing pad (h) W k l k w gl se val form (ı) Phy g st m trogte q (j) B hypt quee (k) Apt o q (F m T E S yd O E my th T Co stock 1935)

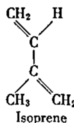
ternal pleopods are operculate and cover the other pleopods *Asellus Ianira* and *Jaera* are genera of this suborder

Phreatoicidea are laterally compressed isopods living in the fresh water streams of New Zealand and South Africa In general aspect they look much like amphipods

About 3000 species of isopods are known today but it may be estimated that only one half of the existing species have been described *See* CRUSTACEA [R J M]

Isoprene

A five carbon conjugated diolefin or diene having the structure

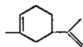


Isoprene

It does not occur naturally but is obtained by the destructive distillation of gas oil naphthas and rubber It is also prepared by the catalytic decom position of dipentene It is commercially available in about 96% purity and is used in the production of butyl rubber

The terpenes may be regarded as multiples of the isoprene unit C_5H_8 Indeed isoprene may also be the foundation for other important plant products such as phytol the sterols and the carotenoids

Isoprene is a mobile colorless liquid boiling at 34 1 C having a specific gravity of 0 862 It exhibits all the characteristic reactions of dienes of this type Isoprene polymerizes readily to form dimers and high molecular weight resins The principal dimer formed is isopropenyl methyl cyclohexene



Polymerization of isoprene during storage can be controlled by avoiding contact with oxygen by using inhibitors such as *tert* butyl catechol and by keeping it at low temperatures *See* DIENE TERPENE [E L S]

Isoptera

An order of the class Insecta commonly known as the termites These insects ha e wings of equal size biting mouthparts and a broad thorax otherwise they are superficially antlike They are ocial in sects which live in large colonies with a caste sys tem and division of labor Termites are closely re lated to the cockroaches and there prol ably was a common ancestor therefore termite have been termed social cockroaches The primitive Aus tralian termite *Mastotermes* has wing structures and an ovipositor similar to tho e of the cock roaches The method of mating in the e two groups is similar with the apices of the abdomens oppo ed Most termites lay their eggs singly but the primi tive forms lay them in a mass like the cockroaches, which produce an ootheca (self generated protec tive covering or case secreted over the egg ma s by the adult in ect) Furthermore ome primitive cockroaches which bore into wood like termites con tain symbiotic protozoa in their inte tines which by means of enzymes digest the wood the roaches ingest and render it available as food Fo sils of both termites and cockroaches occur in the Pale ozoic era of the Carboniferous period *See* SOCIAL INSECTS

The colonizing flight of termites is not a nuptial flight but one for dispersal After a short weak flight the males and females lo e their wing and pairs seek favorable ites for ne ts Only after the new colony is founded does mating take place The rate of egg laying is slow at first but tropical queens may lay as many as 30 000 per day the male or king continues to fertilize the queen for life There is no pupal stage but there are quie cent stages of short duration while molting with marked changes from nymph to adult Termite queens have a remarkable post adult growth due to special diet Physogastric queens of African fun gus cultivating *Macrotermes* reach the length of 117 mm With the kings they may live as long as 25 years

Taxonomy and distribution Over 2100 different species in 6 families and about 180 genera are known including 68 fos il species The I optera may be classified as in the following table and in cludes the number of living and fossil species The total does not include new species

Families of Isoptera

F m ly	N mb f spec		T t l
	L ng	Foss l	
M tot m t d	1	16	17
K l t m t d	8	11	93
H d t m t lae	5	1	3
Rh t m t d	151	8	159
T m t d e	13 8	4	133
U l t m t lae	0	1	1
Do l tf l p	0	16	16
Tot l mbe f spec es	1787	68	18

Isoptera occur in all zoogeographical regions ex cept the Arctic and Antarctic termites reach the height of their de el pment in the tropics the 50 parallels of latitude and the mean annual 50 i o therms outline their di tribution

Nutrition With advancing civilization termites have changed from scavengers in the fore t to in jurious insects The food of termites i cellulo e wh ch is obtained from both living and dead vege tation Cellulo e inge ted by certain termites is both inge ted and digested by their symbiotic in te tin l protozoa which produce the nece ary en zymes (Fig 1) Other termites lacking protozoa btain their cellulo e in a form more directly avail able as food In the tropics termites are e pecially

Fg 5 T rmit m u d d tt g th l d p A trol (H G HII) (F m T E S yd O E my th T t C mst k 1935)

grooming hab t th t is, the you g l ck exud ti n fr m th bodies f the ad lts

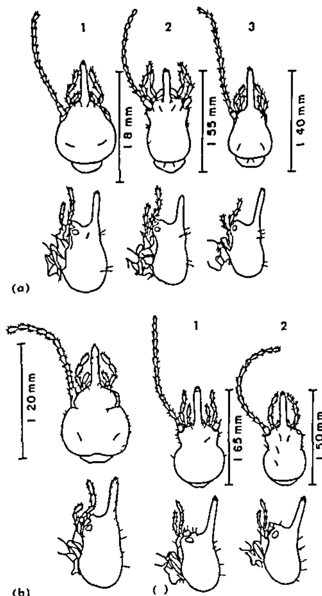
Surplu rep od ct es are l m nated if a p i mary p ir i fu t n g eve if the s n d ct tact t permit th tr smi i f the h b t ry h rm e Thi s e mpl h d in rt fi al l n in the labor tory by n ry p c pti antenn l ta t th gh lay of fi m tal g u e El m na t n ev occ r if t u h g f a tenn e s pre e ted by t l ye f ga ze ⅛ n f m ch the Termitaria The l tes ne t f term te a c n entr t d the tropi s d d ff d i temp ate r gi n Th forme con t cted f o l r arthl ke mat i l a rt o r n th gr und n trees o a m u ds n o b l w th gr d Th d ff ed nest e with n w d or n the earth They m y be m ed f m ar a to a ea w th h nging e ri m ntal o d t In th tropi wh l l l ges f term tar d t the la d ape (F g 5) Thes ests r l a d f v u s z d h p s and m y h towers or h mney Mounds Af ric may b 9 met r he ght M y te m t ia ha e r hedd ng tru tu al d i In Au t l m nd o l ts a nt d w th r fe e c to th n s ays Th r h been a p ogre s e devel pm t in th stru t e f t rm te n t c mpa bl to th t lat foll wed by m n in h t ct es f m a est kysc r e

W th the m e p t tou c nt ated nests th a derly a a g m t f cell a d g l lenes th a pe l r yal h mb fo the p o duct e f rm d nu sert i wh h the egg a d you g r te ded In ests n Indo-M lay nd Af rica galle ies lead to fungu gardens (Figs 6 and 7) whe edible mu h ooms a e cult t d by the t rm t M und t i South Af ica ha e l ee at d by th abo gi es for hu d ed of years In th U ited State l rge c l ny may on t f o ly 250 000 nd i id al whil i the tr pics est m y ontain 3 000 000 inhabit nts There i on t t hythm c act ity d y a d n ght In car

(b)

( )

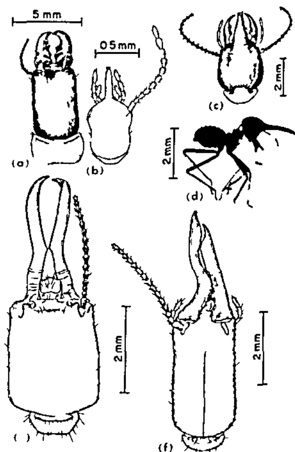
Fg 6 ( ) M d f f g -c lt t g t mt f m J h w g th f g g d (b) C d wh h th t mt f d th d l p d f m th th dl k my l m f th f g lt t d th g d s (F m T E S yd O E my th T m t C mst k 1935)



F g 3 Dorsal a d side views of heads of nasut form term tes to show polymo ph m or d fference fo m of sold ers of the sam spec es (a) Th ee typ s of sold e present majo termed ate and m or (b) O e type of sold er present (c) Two types of soldier pres nt ma jor and m or (F om T E Snyder O r E emy th Te m te Comst k 1935)

The soldiers defend a colony when it is invaded by ants Primitive soldier termites have sawtooth man dibles (Fig 4) but later there evolved a special gland in the front of the head with an acidulous secretion which superseded the mandibles in many termites Among the termites intermediate between the primitive and highly specialized form both mandibles and frontal glands function In the nasu tiform termites a viscous liquid is ejected as a special and effective form of gas defense In other highly specialized termites the mandibles are mark edly asymmetrical and could not be used for biting but are used audibly to snap or flip the insects away from danger or they may be merely used for signaling to warn of danger The workers and sol diers live only 1–2 years Each year large numbers of winged exual adults leave the colony to found new colonies

Evolution of castes The caste system and the oc currence of sterile forms are difficult to explain un der the various theories of evolution The castes or different types of termites in the same colony are not distinguishable until after the third molt when they can be separated into the sterile and repro ductive forms The determination and regulation of the castes can best be explained by the inhibition theory Males females and soldiers ecrete ecto hormones which inhibit the nymphal development of individuals of the same sex or caste as that of the form secreting the hormone In small colo nies where the primary reproductive adults are functioning fully the development of additional supplementary forms is inhibited by the ecretions of the parent reproductive adults Each ca te if pre ent in the colony in sufficient numbers tends to delay or inhibit the development of individuals of the same caste by a hormone regulation These secretions are transmitted to the young by the



F g 4 Sold e t rmites from the American tropics w th d ff e t types of def se organs (a) He d of a pr m t ve *Kal t mes* w th b t g jaws (b) Head f a highly p cial zed s t form te m t w th nasu for def e or ch mical w fa (c) He d of ld er w th both j ws and n sus (d) L t al silhouette view f similar ld er (e f) H ads of old e s dapted for fl ppl g (F om T E S yder O E my th Te m t Comstock 1935)

salts. S b tit tion reactions s h s nitratio sul fon ti br mi at o a d me curat n are b- served

Phe yl thylam es (II) re start ng p i t in tw g l yntheses The B schler Nap lsk m thod ycl ze a A cyl ted de at e (III) with phosph rus o y hlor d to 3 4-d hyd o qu o- lin (IV) The P ct t Spe gler seque c erts phenylethyl m e (II) by e cti w th a ald hyde to an im e (V) wh ch cy l es the pres en ol mine l a d to 1,2,3 4-t trahydr soq n olin (VI) Dehyd ge t n f e th 3 4-d hydr 1 2,3 4-t trahyd q l e by chem l ca alyt methods is g ne lly c mpl cated that f lly atu ated isoqu l es (VII) e re d ly obtai ed In n th r k d f ynthesi (P m ran F t h) If i a d ed t y l anil (IX) p od ced by the act of m a e- tal (VIII) nd r m t c ldehyde

When th m ti i g i phe yl thyl m (II) a tivated by ph n l hyd xyl gr p p to the point f cycl zat o the Pi tet Sp gl e- ctio (V VI) oc u s nd r pt ally m ld d t n B o ynthes s of i qui l ne pl t p od ucts p oceed by th s k d f p o es

Important derivatives 1 2,3 4-T t hyd i o- qu l nes bt ned i P t t Sp gler sy th ses, r by red ct n f 3 4-d hyd o oqui l es 1,2-d'hyd soqu n line r f lly m ti i qu li es. Furth r hyd oge ati o pl t m c ta ly t n l d i mpletely t r ted de ahyd o- q n l es 1 2 3 4-Tetr hyd oq ol es o tho-substituted b zyl m nes th b c ty of wh ch is compar ble t that f al phati am n

Sulf at on f isoqu l e w th l um g es ma nly -oq l 5- lf c a d H ghe tem pe t es g nc g m unts of q l e- 8-s lf n c d d i q l 7 lfon c id Th cti f i q line w th n tr c lf ri d g es ma ly 5-n t qu l e t geth with som 8- t o soqu l e B mi t on nd me u r ti f th 4 po t Sod m de r ts t y eld 1 m n soq l N leoph l t ty t th isoq l e 1 po t h w by th sod m de p oces a w ll a by mb t f qu l th g m tall ompou d t gi e 1 b t tuted deri t es and by th h d e ct ty f 1-h l soq l t d pl m t p es es

1 Chl ro soq i ol nes have b en obtained by diazo- tizati n f 1 amin oquinoli n c centrated hy d chlor ac d 1 Hyd xyisoq n line or i ocar bo tyril e t in aq eo s s lutio almost e t rely in the 1-oxo f rm (X) Other hydroxyi oquinoli es deviat l ttle fr m the norm l beha i of phenol 1 Methyli oquinoli e and t much les er d g ee 3-methyli oq line po es react e methyl g up Quat r zation enha es thi reacti ity

Is qui line 1 ca boxyl c a d (XII) h been bta ed d rectly by way of i quinol ne-1-car bo ldehyde by oxidati n of 1 methyli qui ol ne (XI) The m cid i acces ble fr m i q ino- l e thr gh the Re ert c mp und (XIII) 3-M thyl soq nol e n be o di ed with el ni m d xid fir t t i oq n l ne 3-ca bo aldehyd a d th w th hydr gen pero ide t i q in li e 3- arb xyl a d Other i qu ol ne arb xylic a ds are a lable hydroly s p oduct f om th esp nd g ya der ti e all f which can be obta ed by nte ct n f the br moi quino- l ne with cup o ya id Is qu noline 1-ca b yl c ds a e re d ly dec boxylated

With me x ept n the cti s of quino- l e h a al gou c te p t th ea t on f q l e [W J GE]

B bl og phy R Adams (ed) *O g nic R c t* 1 6 1951 R C. Eld field (ed) *H t o y l C mp ds* 1 4 19 2

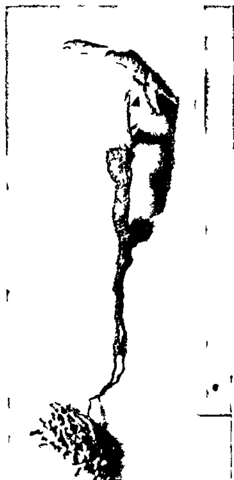
Isostasy

A theory f hyd st t c equ l b i m th vari us parts f th arth cru t M ny sc nt ts w j dge th theory w ll onfirmed as t be n d r d a b law f g l gy B F H well J 1959 t ted t in h xpl it t rms all

ton tree nest in Jamaica consisting of 500 000 indi viduals the traffic from the nest through shelter tubes was 8000 per hour during the period of great est activity shortly after midnight

Within the mound nests the temperature and hu midity are higher than outside The humidity may be as high as 92% In nests of the fungus growers air heated in the fungus gardens is circulated through the nest so that the high concentration of carbon dioxide is dissipated through the walls and cooled oxygen rises into the nest In the Lower *Congo region of Africa remarkable small ovoid sub* terranean *Apicotermes* nests occur with variou progre sive types of ventilation pores

Control For the purpose of preventing and rem edying termite injury these insects may be classed as subterranean dampwood drywood carton and mound builders and harvesting types Damage to living vegetation by subterranean termites can be remedied by saturating the soil with low percent ages of water emulsions of chlorinated hydrocar *bons Structures can be protected against all types* of termites by securing impervious foundations and the use of mechanical and chemical barriers Where dampwood termites injure woody vegetation



Fg 7 Fru t ng body of a f ngus (Agar e) g ow i g f m a b t of the fung s ga d f a J a e term te (Fr m T E S yd r O r E emy th T m te C mstock 1935)

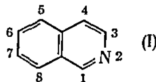
poison dusts may be injected into the galleries Where buildings are damaged by dampwood ter mites dryness should be secured by structural methods Damage to structures or furniture by dry wood termites can be remedied by the injection of poison dusts into the galleries or by fumigation with lethal gases Termites in carton or mound nests can be similarly killed Harvesting termites can be controlled by the use of poison baits or their nests can be poisoned or fumigated *See* IN SECTA INSECTICIDE [T E S]

Isopycnic

The line of intersection of an atmospheric iso pycnic surface with some other surface for in stance a surface of constant elevation or of con stant atmospheric pre sure An isopycnic surface is a surface in which the density of the air is con stant Such surfaces are also designated i osteric surfaces because the e surfaces in which the pe cific volume is constant coincide with the recip *rocal conditions of isopycnic surfaces since* den sity is the reciprocal of specific volume On a surface of constant pressure isopycnics coincide with isotherms because on such a surface density is a function solely of temperature On a constant pre sure surface isopycnics lie close together when the field is strongly baroclinic and are ab ent when the field is barotropic *See* BAROCLINIC FIELD BAROTROPIC FIELD SOLENOID (METEOROLOGY) [F S]

Isoquinoline

One of a group of organic compounds containing a benzene ring fused to the 3 4 positions of pyridine Isoquinoline (I) is a representative member of the group *See* HETEROCYCLIC COMPOUNDS QUINOLINE Quinoline produced from coal tar contains approxi mately 1–4% of i oquinoline and it is an important ource of the latter material Separation is effected by electi e extraction of the more basic isoquino *line with acid or by selective* precipitation and fractional crystallization of salts Repeated frac tional freezing and distillation have furnished pure isoquinoline Many plant alkaloids especially tho e in the cactus opium and curare groups are iso quinoline deri atives



Properties and preparation Isoquinoline is a c lorless odorous liquid with bp 243 3 C mp 26 5 C and n_D^{30} 1 62078 Its stability to acid base *or heat is high I oquinoline which is somewhat* more basic than quinoline (the pK s are re pec ti ely 5 14 and 4 51) can be protonated to f rm simple salts and alkylated to form quaternary

lts. Sub tit t re ction uch s nit t n sul f n n, b m at o a d me n ation are observed

Phenylethyl mine (II) re t rting p int in two g ne l y the es The Bis hler N p e alski method cycl z an N cyl ted der ati e (III) with ph ph ru o y hl d t 3 4-dihyd o soquinol (IV) The Pi t t Spengler eque ce on erts ph lethylamin (II) by eact on with n aldehyd t an im n (V) whi h ycl z s in the p esen f min ral acid to 1 2,3 4-t tr hyd o soquinoline (VI) D hydroge at n f e ther 3 4-d hydro 1,2 3 4-t trahyd o qu n l e by hem l r c talytic method is g n r lly un ompl c ted that fully n s tu ated i q nolines (VII) e readily obtai ed I n th ki d of synthes s (P me anz Frit h) ull c d ed t cy l e a il (IX) p od ed by th rea ti of mi o e tal (VIII) and r m t c ald hyd

When th om t r g ph yl thyl m e (II) a t ated by a phe ol c hyd yl g p p t th po nt f cy lizat o the P tet Sp gl r recti n (V VI) oc s u d x ept lly mild o d t s B o ynth s of oq n l ne pla t p d ucts p oceed by th ki d f pr ces

Important derivatives 1 2 3 4-Tetr hydr oq l ne ar bt ed n P t t Spengl r yntheses, o by red ct n f 3 4-dihydroi qu l es 1 2-dihyd o soq n lines or fully omat oqui oli es. F rth r hydr g n ti plat m c t l t an l ad t c mplet ly t ted dec hyd oquin li e 1,2 3 4-T tr hydroi oqui ol nes a e o thos b tituted benzylam es th b city f whi h is comp ble t th t of liphati ami e

S lf n ti of q l n w th ol um g ves mai ly soqu l ne-5- ulfo ic cid H gher t mperatu es g inc g amo nt of i qu n l ne-8- lf c d d i oqu l 7 lf ni a id The rea ti n of qu n l w th n t c lf r id g es ma ly 5- t soq n l tog the w th some 8- t isoquin l ne B om t n a l me cu to f or th 4 po ti n. S d mide rea ts t y ld 1 ami soqu ol N cleoph l a t ty at th isoqu l n 1 po t i h wn by the od m d proces a w ll by comb n t f s qui ol e h rg n m t ll c c mpo d to gi l sub ti t ted d ri tives a d by th e ha ed e t ty I Thal soqu l e t d pl em t p oc e

1 Chl r oqu n lines ha e been obtained by diazoti ation of 1 ami oquinolines in concentrated hy d ochloric acid 1 Hyd xyi oquinoline or isocar b styr l exists in aque s l t on almost entirely in th 1-oxo form (X) Other hydroxyi oquin l ne d iate littl fr m the normal beh ior of phe ols 1 Methyl oquinol ne and to a much le er degree 3-m thyli oqu noline p s ess r ctive methyl g oups Quaternizatio enhances th s reacti ty

Isoqu nol n 1-carboxyl ac d (XII) h s been obt ined d ectly or by way of i qui line 1-car boxald hyde by ox d tion of 1 methyli qui oli e (XI) The sam acid a essibl f m i quino-l th ugh the Rei rt compou d (XIII) 3-Methyl oqu nol e an b xid zed with elen um dio de fir t to o q noli e 3-carboxaldehyde and thence w th hydr g n per de to i oqui line 3-c rbo ylic cid Oth r o qui line rboxyli acids ail ble hyd olysi pr du ts from the cor e p nding va deri ti es all of wh ch can b bta ned by nt acti n f the b om soqu oli es w th cup ou cyan de Isoquinoline-1 car b xyl a ds e readily d ca bo ylated

W th om x pt n th react o f oq ol e h n l g u unte p rts i the eact n f qu l e [W J CE]

B bliog phy R Adam (ed) *O g c Re c ti* 1 6 1951 R C Elderfield (ed) *Het cycl c C mp d* 1 4 1952.

Isostasy

A theory f hydr tat q libr m in th rio s p rt f the arth s c u t Many c e t t now i dge th the ry o well c fi m d to b con de ed ba l w f ge l gy B F H well Jr n 1959 tated it in s h xpl c t term a " ll

large land masses on the earth s surface tend to sink or rise so that given time for readjustment to occur their masses are hydrostatically supported from below except where local stresses are acting to upset equilibrium *See* TERRESTRIAL GRAVITATION *see also* EARTH [C V C]

Biblio raphy W A Heiskanen and F A Vening Meine z *The Earth and Its Gravity Field* 1958 B F Howell Jr *Introduction to Geophysics* 1959

Isotach

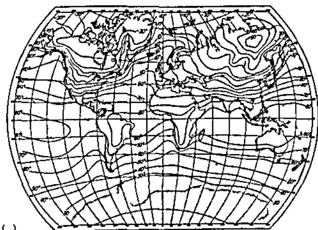
A line along which the speed of the wind is constant Isotachs are customarily represented on surfaces of constant elevation or atmospheric pressure or in vertical cross sections The closeness of spacing of the isotachs is indicative of the intensity of the wind shear on such surfaces In the region of a jet stream the isotachs are approximately parallel to the streamlines of wind direction and are closely spaced on either side of a core of maximum speed The term i ovel is used synonymously with the term isotach *See* JET STREAM WIND [F S]

Isothermal chart

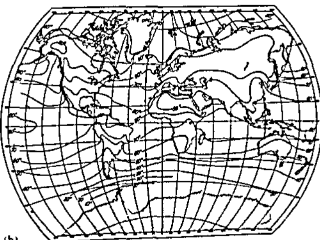
A map showing the distribution of air temperature (or sometimes sea surface or soil temperature) over a portion of the earth s surface or at some level in the atmosphere On it isotherms are lines connecting places of equal temperature The temperatures thus displayed may all refer to the same instant may be averages for a day month ea on, or year or may be the hottest or coldest temperatures reported during some interval

Maps of mean monthly or mean annual temperature for continents hemispheres or the world ometimes show values reduced to sea level to eliminate the effect of elevation in decrea ing average temperature by about 3 3F /1000 ft Such adju ted or sea level maps represent the effects of latitude continents and oceans in modifying temperature but they conceal the effect of mountains and highlands on temperature distributions The first i othermal chart prepared by Alexander von Humboldt in 1817 for low and middle latitudes of the Northern Hemisphere was the first u e of isopleth methods to show the geographic distribution of a quantity other than elevation

These maps are now varied in type and use Isothermal charts are drawn daily in major weather forecasting centers 5 day 2 week and monthly charts are used regularly in long range forecasting mean monthly and mean annual charts are compiled and pul lished by most national weather services and are presented in standard books on for example climate geography and agriculture *See* AIR TEMPERATURE TEMPERATURE INVERSION [A C]



( )



(b)

Wo ld sea level isothe mal charts ( ) Janu ry (b) J ly (After H R Bye s Ge eral M t o l gy McG w H ll 1944)

Isothermal process

A frictionless expansion or contraction process accompanied by heat addition or removal from the system at a rate just adequate to maintain a constant temperature of the gas while the proce s is going on

Because the internal energy of an ideal gas is a function of the temperature alone and because the temperature remains constant in this process the internal energy stored in the system also remains constant

In an isothermal expansion process the heat added to the system is precisely equal to the work done by the isothermal expansi n for tl ere is no change in the stored energy of the system

$$Q_T = W + U_2 - U_1 = W = \int_1^2 P\,dV$$

where Q_T is the heat transferred at con tant temperature T W is work U is internal energy and V is volume But from the perfect gas law

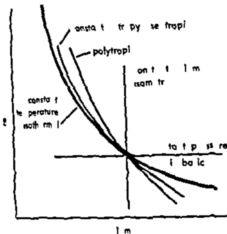
$$PV = mRT = \text{Constant} = C \quad \text{and} \quad P = C/V$$

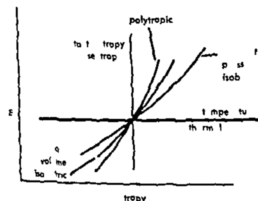
where P is ab olute pressure m is ma and R is the ga c n tant Thus

$$Q_T = \int_1^2 P\,dV = C\int_1^2 \frac{dV}{V} = mRT \ln \frac{V_2}{V_1}$$

$$= mRT \ln \frac{P_1}{P_2} = mT(s_2 - s_1)$$

wl ere s i entropy The i tl ermal re ersil le com





soth rm l p ess mp d t oth th rm dy m rocesse

p ess on p on p is omp ed to other de l g s p oces es th d gr m S e THERMO-DYNAMIC PROCESSES [J B]

Isotone

O f t o m toms which di play c n tant d ff *n e A − Z betwe* their m n m b *A* nd th atom numb r *Z* Th s d pite d ff r es n th total n mber of n le con t t uent th *umbe* s f neut o n th nucl of sot nes th m The n mb s f naturally oc rri g ot es p d u f l e d nce ncern ng th tab lity *f pa t cul r* n ut n config a t F e mple the *rel ti* ly l ge n mb r (x d en r sp t ly) of n turally ccur ring 50 and 8 n t n t s ggest that th se nu l fig rati n espec lly table On th the h d from th f ct th t m t at ms with odd n mbers f utr e an t ne m y cl de th t dd n ut n co figu ti e l t ly u t bl S NUCLE R STRUCTURE [H E D]

Isotope

O *f tw* mo t m h g the same t mi numb *Z* b t d ff e t m n mbe *A* Th nucle f sot pes ta n d nt l mbe l p t n but d fferent number of neutrons Thus although they differ in ma s i otope belo g to the ame chem c l l me t For mo t elements both stable and ad oacti e isot pes are known the latte how e er unless ccurri g naturally are di cu s d el e-wh re *See* RADIOISOTOPE

The occ rrence and deg e of i otopy among the 83 elements that are fo nd n nature in sign ficant am unts ha e been ascerta ned by mean f ma s pect omet r studi (*s e* MASS SPECTROSCOPE) Ti ($Z = 50$) for example po e es 10 stable isotope ($A = 112$, 114 115 116 117 118 119 120 122 and 1 4) a larger number th n any other lem nt On the oth r hand 0 element po es n is top s ea h of these c ns ts of o e typ of atom nly Su h el m nt are a d to be ani otop c The rema ni g 62 elements po s i ot pe ranging in numb r from tw to ni e Altogether 287 d fferent at m peci are found in appr ciabl quant tie in nature (ee Ilu t at n)

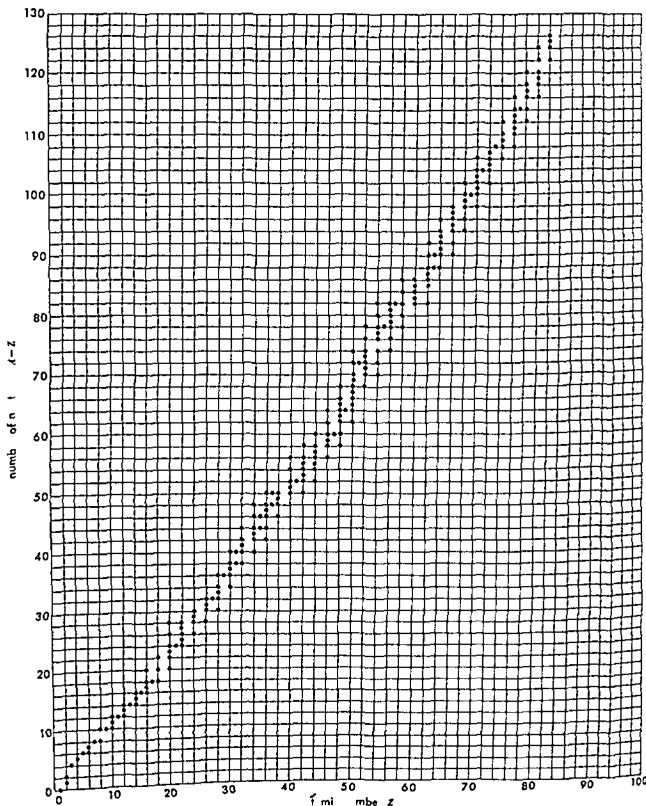
Nuclear stability Regul rit es in the table of naturally ccurring atom r veal ert in facts c n ce ni g nucle r f rces The 287 differ nt atomic spec e a e bd v ded as f llows 168 e en e n (e en n mber of proton and even number of n u t ons) 57 e en-odd 53 odd even a d 9 odd-odd The tat sti s d sclo e th pairi g t nden y f nuclear con tit ent a d establish that there is n sign fi ant differ nce in stabil ty betwee odd pro-t n d dd n utr n o figu tio Th e istence of a elati ly l rge numb r f isotopes pro ides e dence for a p rtic la ly tabl proton configura t on O th b si fo xampl th extra tability as oc at d w th the 50-prot e figur ti n (th t i tin) h s be n inf red *See* NUCLEAR STRUCTURE

Isotopic abundances M ch w rk ha b en don n determin ng elat e bund nces f *isotope* For many el m nts the relat e i top c bundances how no nat ral va t on O th ther hand the otopic on titut o of e al elements is t ongly d p dent up the h story of th i ple that be ng e tigated In th cases the aria ti n n top c con titut n can be ttr buted to c rt n atur l pro se nd the st dy f th vari ation pr id a p w *rf l means* of elucidating the pr c s e them l es d of ascertainin the p riod f tim in which th sample under in estiga t n h bee subj ted to them Some detail of th type of tudy e now g en mme g with d u i n of bno m l i ot p c abu d nces ca ed by ad o t e dec y

Am g the t rally ccurring at m spe i s e a f w wh h are adi i e Th *half l es* (the a erag t me nt rv l requ red f r one-h lf of a h t nderg d a t e d c y) are ery l ng b t k ow The mo t mportant m mbe of thi gro p e K Rb Th ²² U a d U Th th e la t n med re t n f med by m i n of mplic t d q nce of α β d y) int tabl i t pe f le d (Pb Pb and Pb re pe ti ly) One m y the ef re by det mi g th p e nt m u ts f Th and ad geni Pb in g n e omp te the age f the o e In an

analogous manner the age of uranium ores may be deduced K ⁰ decays to either Ar^{40} (by β emission or K electron capture) or Ca ⁰ (by β emi sion) The K Ar⁴⁰ decay is proving increasingly useful in the geochronology of potassium ores which are widely distributed in the earth s crust The Rb^{87} decay (to Sr^{87} by β emission) is also utilized in the dating of minerals In each of these cases the radioactive decay manifests itself as an altered from normal isotopic distribution in the daughter element *See* RADIOACTIVITY ROCK (AGE DETERMI NATION)

The other altered i otopic di tributions that are found in nature result from small differences in the physical and chemical properties of the isotopes of an element These differences lead to i otopic frac tionation (separation into different portions) chiefly via the proces es of diffusion evaporation



Ch t of stable isotop s

and chem c l excha g The f t nations produ ed by these p oce es a e mo t p onounced am g the lighte l m t where the perc ntag m d ff e between isot pes e la ge
N rmal hyd ogen con t f H (99 985%) and H (0 015%) Th e t rd arily l g percent age ma d ffe en bet een the e otopes re lts m n tu l fr t t on th t a e m ch l rger than f any oth eleme t The tw stable i topes of arbon ha e th appr x m te bundance rat o C/C = 89 3 b t ma y nat ral mples d pl y l ge d f qu tly e plicable de t ns f m th s val e S m l ly s gnific nt riat ns hav been fou d in th O /O and S /S abund ce rati s. I e tigat s f thi typ dema d except- i n lly car ful (hem l) ampl p ep ati and p ec (m pe t ometri) isot p c a ly es. Th r ult are of great v l e t geophy ici t a d geoch m ts n u d tand ng the r le pl yed m n tu e by the pr esses wh ch lead to the fra ti nat of sotopes. Se GEOCHE ISTRY GEOPHYSICS

Use of separated isotopes Ce t in is top po ess pec lia p operti e not po ss d by othe isot p f th el ment. I c es whe e th pr perty i ffic tly s ght aft the top in q e ti n h bee epa at d from ts f llow i whole scale am unts. Fo nst ce be au of the effi y hea y hyd gen (H) t m de ti g n tr ns i n cle r t la g qua tit f H (n the rm f heavy wat r) h e been i lated from H th mp rt nt xampl th s pa t n f e l w tr n fi le U² f m the m ch mor bu dant U Sep at d s top s ar a lable m t el m ts nd make p s bl th u q o- l tudy f otop c effects a oppo ed t elemen al eff ts. S Is TOPE SEPARATION (STABLE ISOTOPES)

Th u f m ny b ochem cal d othe rea i s an b x m ed by nt d i g t tag bnorm l m xtu e of s t pes d e am ning at i bseque t t ge the top c c n t t t f the el m nt o cerned Th tr r techn qu ut lizes d a tive t pes wh e th y a il bl but n u t ble d ti i top e i ts f e th n tr gen yg T a work i l i g th tw m t m t be d e with st bl t p m t re hich ha be n r ched i n m c nst tu nt S TRACER RADIOACTIVE.

Atom c weight A k wl dge f th ma a d b i d n e f each of the t p f el ment perm t the lc lat f t a ge at mi ma Exp es ed n the h m al le th s the h m ic l t m w ght. F ll t p eleme t (I wh h any ert ty i t p c o st tuti d appe s) and f ma y i ot p c eleme ts a w ll th phy al app ch yield m e ur te al es f r th at m w ght th n d th t d ti nal h m l method S ATOMIC WEIGHT

[H E D]

B bl g phy F W A t n *Mas Spe t nd Isot pe* 1942 *P d g I t ti al Sympo- m I t p S pa ation* 1958

Isotope dilution techniques

The i troducti n of rad tope i to stable i otopes f an element in o der t make v lume m s and age me sureme ts f the elem nt The technique may be t b de cribed by gi ing imple example If knowledge f the t t l amo t of water p e ent in a contai er i de ired a mall amount of l bel d water D O or T O is added t the H_2O in the ntai er F r the purpo e of the m urement this am nt an be con dered to be 100% After the lab l d d uteri m or tritium is completely m xed with the w ter n the con t ner a s mple of the m xture f unit volume p rhap l m s rem ed and the am unt of labeled w ter in it determined If thi am unt is f und t be *a*% the the t tal m unt f water in th c ta ne will be 100/*a*

I the applic tion th m s f an elem nt may b det rm ned In th s a e th radioi otope is i trod ced and m xed sample is w thd awn a d b th the mount of rad is tope and the mo nt f t ble ch mi l pre nt are m a red The rat o f these tw m unts c lled the p cific acti ity an be e p essed a % d e/mg For example od um 24 is admi tered t a pati nt and the pec fic ct vity of sod um in the blood (the am unt of labeled dium d ided by the am nt f stable sod um) determ ed Thi permits measeme t of the total amount of excha ge ble sod m with n the body

All i tope dil t n t ch ique may be c n s de ed to be n ext on of the e simple measureme ts A m re c mpartments r cont i ers are added to the ystem howev r th analysi bec mes i cre gly diffic lt F rthe m e the ass mpti n of immed te a d mpl te m x ng will no l nger be al d De pite the e diffic lt es th underlyi g p nc ples e ide ti l with the mpl ne- ol me a e and i t p d l ti n tech que h e fou d a wide a g f appl t i med e b ol gy nd du t y

Is t pe dil ti n is ft n u ed i n lyt al ch m i t y a es wh e a q ant tati e xtr ct of the s bst e to be ayed is diffi ult A mall q an t ty f lab l d subst c dd d t th ample b fo e ep ti n and a aly i The xtr tio i th n a ri d t w th ut ega d to c mpl te es a d n rb tr ry mple s emo ed f a aly f the chemi al sub ta e a d f th labeled subt nc F m th at of the in tial a d fi l c t ty the chem al a ay may b corrected t gi e th rre t mo t f chem c l i the ampl b f re xt a t n

Isotop dil t n te h iques h e al o f und n a n ppl ti s in g ol gy He e th y are u ed t d t rm e the ab nd n a d d tribut n f t a e c tit ts pe lly n meteo te and t m ke g l g al ag det rm ti ns f r ex m pl th d t mi t n f th ag f a m a by the p t m g n m thod use Ar sp ke to d t mi e the r d og nic Ar the ample The A a dec y p d t f K reta ed w th n the

mica In the e applications mass spectrometers are u ed to make the sample analysis *See* ROCK (AGE DETERMINATION) [G L B]

Isotope separation (stable isotopes)

Many chemical elements always occur in nature as a mixture of everal isotopes The isotopes of any given element have identical chemical properties but there are slight differences in their physical properties because of the differences in mass of the individual isotopes (*see* ISOTOPE) Thus it is pos sible to separate physically the isotopes of an ele ment to produce material of isotopic composition different from that which occurs in nature Al though these separation processes are all quite difficult and expensive to carry out they are not inherently different from the usual operations em ployed in the chemical process industries

The separation of isotopes is particularly impor tant in the nuclear energy field because individual isotopes may have completely different nuclear properties For example uranium 235 is used as a fuel for nuclear chain reactors heavy water (deute rium oxide) is used as a neutron moderator in nuclear chain reactors and deuterium gas is a pos sible fuel for thermonuclear reactors Separated isotopes are also used widely for research on the structure and properties of the nucleus

The process which is best suited for separating the isotopes of a given element depends upon the mass of the element and the quantity of separated material which is desired Research quantities of separated isotopes are best prepared by electro magnetic separation in a mass spectrometer For example gram quantities of many separated iso topes have been prepared at the Oak Ridge Na *tional Laboratory using the large electromagnetic separators* which were built during World War II The electromagnetic process has the advantage that a fairly complete separation of two isotopes can be obtained in one operation

When moderate quantities of a eparated isotope are desired thermal diffusion may be used Al though thermal diffusion requires a large energy input this is more than off et by the simplicity of the equipment absence of moving parts and high separation obtained in a small volume

In the large scale separation of stable isotopes the best processes are tho e which have the highest thermodynamic efficiencies Reversible proce ses involving distillation and chemical exchange are best for separating the light isotopes such as deu terium For heavy isotopes such as those of ura nium howe er no appreciable eparati n is ob tained by the reversible proces e and some type of irreversible proces such as gaseous diffusion must be used Although reversible processes have in general higher efficiencies than irre ersible one the absolute efficiency of any isotope separation process is very small

Gaseous diffusion This process has turned out to be the most economical for the eparation of the i otopes of uranium It is based on the fact that in a mixture of two gases of different molecular weights molecules of the lighter gas will on the average be traveling at higher velocities than tho e of the heavier gas If there is a porous barrier with holes just large enough to permit pa age of the individual molecules but without permitting bulk flow of the gas as a whole the probability of a gas molecule passing through the barrier will be di rectly proportional to its velocity From kinetic theory it can be shown that the velocity of a gas molecule is inversely proportional to the square root of its molecular weight so that the efficiency of gaseous diffusion will depend on the ratio of the square roots of the molecular weights of the two gases present *See* DIFFUSION IN GASES AND LIQUIDS KINETIC THEORY OF MATTER

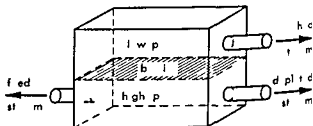
The only uranium compound which is a gas at a reasonable temperature and pressure is uranium hexafluoride UF The two isotopes to be separated are U F_6 and U $^{8}F_6$ and the efficiency of sep aration depends on the quantity

$$\sqrt{U^{3}F_6/U\ F_6} = 1\ 0043$$

Since this number is clo e to unity the separation is very small in any one step of the proces

The separation of the isotopes of uranium in the United States is carried out in three plants oper ated for the Atomic Energy Commission which are located at Oak Ridge Tenn Paducah Ky and Portsmouth Ohio In each of these installations natural uranium containing 0 71% U ^{3} and the balance U ^{38} in the form of UF_6 gas is separated into an enriched uranium product containing more than 90% U ^{5} and a waste containing about 0 3% U The British have a gaseous diffusion plant at Capenhurst and the Soviet Union has facilities at an undisclosed location

The success of the gaseous diffusion process is dependent on the performance of the single diffu sion stage In each stage UF_6 gas is compres ed passed through a cooler to remove the heat of com pression and then admitted to the vessel containing the porous barrier (Fig 1) About half the gas entering the essel diffu es through the barrier and pas es to the next higher stage This diffu ed gas contains slightly more of the U i otope The un diffused gas is slightly depleted in the U ^{35} isotope and passe to the next lower stage



Fg 1 Ga eo d ff io stage (F om H Ether ngto d Nucl ar Eng r g Ha dbook M G aw H ll 1958)

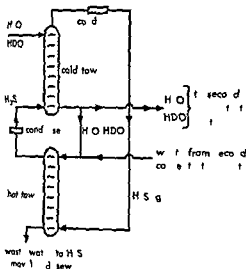


Fig 2 Dual te p tu e H_2S-HDO cha g Th d prod ct a m xtu of H O HDO a d D O th el tive b d f D O a g the l t st g o R St ph I t od ct to N l E g i 2d d McG w-H ll 1958)

Seve al thousand d id al st ges re required bri g bo t the nece ary o r all hange in mpo si The comb nati n of stage is known a de, a d the s ade wh ch brings bout e ep r tio with the le t work is known as an tal c sc de The s ze f the stages varies tremen ly th e fe d g the natu al urani m i to the sc de are the la gest a d th final product t g s the m llest.

N ck l-cl d piping nd pro e s equ pme t a e ed to h dle the UF gas Thou a ds of pump ol a d co tr l i st ment a e r qu ed The ectri pow requ ment f th ga e u diff n p oce s a e la g app oximately 10% f th al lectric po er tput of the Un ted St tes has en requ red to op at the th e d ff on pl nt. ec nt ye rs

Th g seous d ffu n p ess wa orig nally de- p d a a m an f prod c g h ghly enr ched i m f r tomi b mb At p esent much of the r hed ra ium p odu ed by ga eou d ff si n i d as fuel f ucle r re cto s

Chemical exchange The ch m cal exchang sses h s p ed to b the mo t effici t for parating ot p s f th l ghte el ment Th oce s i b ed on the f ct that if equilib ium i bl hed b tween fo example ga a d a liq f ph se th mp tion f th i otopes will be r t a th tw ph a e Th s f hyd ogen g s gh m equ l br m w th w te it s fo nd at the ratio f heavy hydr g n (de t ium) t ht hyd og n i seve l times gr t the wate n in the hydr g n ga By repe ti g th p o ess a u t ble c cade t is p ble t ff ct a sub- tial sep rat n of the i t pes w th a rel ti ely ll n mber of st ges

The chief use of chemical exchange is in the la ge scal produ tion of heavy water A dual tem perature exchange reaction between water which c ntain HDO and D O molecules as well as H_2O molecules and hydrogen sulfide (H_2S) gas for the p mary separation of heavy water is u ed at the Savannah River plant. The separation is carried out in a series of hot towers operating at the boil i g point and cold towers operating at room tem pe atu e (Fig 2) In each tower liquid water pa es downward countercurrent to the r sing H S gas The relative di tribution of heavy and light w ter is affected by temperature and the success of the pr cess is d termined by the difference be twee the c centrations in the hot and the c ld towers

Ch mical e change has also be n used for the l rg scale separat on of other isotopes For exam ple the i otopes of boron ha e been separated by fractional d stillation of the boron trifluoride–di m thyl ther omplex

Distillation The separati n of isotopes by dis- tillation is much le s efficient than separation by othe meth ds D stillation was used during World W II to produce heavy water but the cost was h gh and the plants are no l nger in existence The only p esent la ge- cale use of distillation is at Sa annah R ver where fractional d stillation is used to con ntr te the prod ct from the dual tem p atu e process (12–16% D_2O) up to 95–98% D O See DISTILLATION

Electrolysis Electrolysis of water is the olde t la ge scal m thod of pr du ing heavy water Un de f orable co diti ns the ratio of hydr gen to de te i m in the gas lea ng a cell in wh ch water is elect oly ed is 8 times the rat o of these isotopes in the l qu d In spit of th s h gh degree of separa ti n el ctroly is can be us d only where elect icity is ery cheap as in Norway beca se of the l rg p wer onsumption per pound of D_2O p od ced Electrolys s is u ed in the U ited States only as a fini hing step t c n entrate t final product sp cifi cat n

Electromagnetic process El ct omagnetic sep- at on was the m thod hi h was first used to p o e the exi tence of is tope The mass pectrom eter and ma s spe tr gr ph re still widely u ed by phys cists a a ea ch to l (se MASS SPECTRO-SCOPE) In th electrom gnet c p ocess ap r of th mate ial to b a alyzed are ioni ed a celerated n n electri fi ld and e te a magnet c field which auses the ons to be bent in a ci cular path (F g 3) Since the l ght ons have less m mentum than the he vy ions they will be bent through a c cle f m ll r radiu and the two is t pes can b sep ated by plac ng coll cto s at the p pe locatio

D i g W rld War II a large lectromagnetic eparati n pl nt was built at Oak R dge to parate th i otopes f an um Th l rge ma s pectr m et r d th re we e r ferred to by the code name Calut on a contraction of California Un er ity

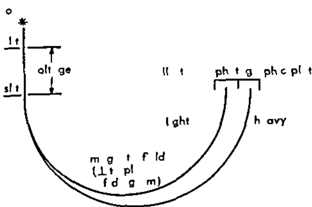
cyclotron The first kilogram quantities of U^{235} were produced in 1944 With the completion of the gaseous diffusion plant at Oak Ridge the electro magnetic process was found to be uneconomical and was abandoned in 1946 However some of the equipment is still being used to produce gram quantities of separated isotopes for re earch pur poses

Thermal diffusion The separation of isotopes by thermal diffusion is based on the fact that when a temperature gradient is established in a mixture of uniform composition one component will concen trate near the hot region and the other near the cold region Thermal diffusion is carried out in the annular space between two vertical concentric pipes the inner one heated and the outer one cooled Because of thermal convection of the fluid there is a countercurrent flow which greatly in creases the separation obtained in simple thermal diffusion and makes possible substantial separa tions in a reasonable column height

Thermal diffusion has been u ed to separate small quantities of isotopes for research purposes In 1944 a plant was built at Oak Ridge to separate the isotopes of uranium by thermal diffusion How ever the steam consumption was very large and the plant was dismantled when the gaseous diffusion facilities were completed

Centrifugation The use of a centrifuge to sepa rate isotopes has one major advantage namely that the separation depends only on the difference in masses of the two isotopes and not on the ratio of their masses Thus it is no more difficult to sepa rate the isotopes of uranium than those of the light elements A disadvantage of the centrifuge method is that a very high speed of rotation is required to obtain any substantial separation in a single unit

A centrifuge pilot plant was built during World War II but further work on the process was dis continued because of engineering problems in vol ed in the operation of high speed rotors the low capacity of the individual machines and the large power input required to overcome friction *See* CFNTRIFUGATION



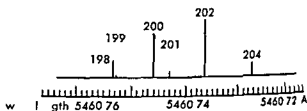
Fg 3 D agram of mass spectromete or Cal t o (Fr m R Steph nso I trodu t o t Nucl ar E g ng 2d ed McGr w H ll 1958)

Nozzle process Isotopes can be eparated by al lowing a gaseous compound to exhaust through a properly shaped nozzle Preliminary calculations indicate that this relatively new method may be competitive with gaseous diffusion for eparating the isotopes of uranium *See* RADIOISOTOPE PRO DUCTION *see also* DEUTERIUM HEAVY WATER NU CLEAR FUELS [R M S V]

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Isotope shift

A displacement of spectral lines which come from the different isotopes of an element This hift in wavelength is caused mainly by differences in nu clear masses and differences in nuclear volumes The first effect predominates in the lightest ele-



I otope sh fts in the g een l e of me cury D shed l nes ind cate the hyp f e struct re compo e ts of the otopes hav ng odd mass n mbers

ments but becomes negligible for atomic numbers greater than about 40 The mass effect in 1 electron atoms results from the variation of the reduced mass $mA/(m + A)$ where m is the electron ma s and A is the nuclear mass and was important in establishing the Bohr theory (*see* ATOMIC STRUC TURE AND SPECTRA RYDBERG CONSTANT) The shift of the first line of the Balmer series between hydrogen and deuterium is 1 325A and this led to the discovery of deuterium The volume effect is im portant for heavy elements and gi es informati n about nuclear structure Deviations from the theo retical volume effect allow an e aluation of nuclear quadrupole moments and nuclear hape A typi cal volume effect is hown in the illustration Though the lines fr m the isotopes with even ma numbers are een to be almost equally spaced the lines for the odd ones do not lie e en approximately halfway between [F A J]

Isotopic spin

A quantum mechanical ariable intr duced for con venience in interpreting nuclear reactions and hyperon decays

In the quantum mechanics of atomic nuclei it is ometime c nvenie t to regard the proton and the neutr n as two different state of the ame p rticle called the nucleon The concept i u e ful as a means of gi ing expre i n to the apparent

harge indep nd n e of t ong n cl ar forces that is, th fa t that p ot n p oton proton n utron and ne tron neutr i t r cti ns are app rently the sam S NUCLEO

A va ble T_3 i int oduced wh ch has the valu $+\frac{1}{2}$ f r the proto and $-\frac{1}{2}$ for the neutron that the harg f a nu leon i $|e|(\frac{1}{2} + T_3)$ | | be ng the absol te alue of th cl rg f the electron o proton. The i o s kind f ex ha ge forces wh ch pl y a r le i nucle r theo y th n find mpl ex pres by treat ng T l ke a c mpo ent of quan tity formally resembl ng an angi lar momentum ect r T f r ch nu leo wh ch is call d the i o-topic pin r i pin The name come from the f rmal an l gy to p n and is somewh t nf rtu n t m e it doe not have an thing t do with ct al p n Ne erth less th a ne i o well e tab l hed age that ther is l ttl ch nc th at it will be cha ged

Individual n rgy level of compo it nuclei a be ign d a q a tum n mbe T wh ch a $T(T+1)$ p e e t the mag itude of the ect r resultant f the ndivid al sot p c p ns of the c nt t n cleo s The e ultant T f ll the n leo n n cleus c nta n g A nucleons of which Z are proton and $(A-Z)$ a e neutron s

$$T_3 = \tfrac{1}{2}Z - \tfrac{1}{2}(A - Z) = Z - \tfrac{1}{2}A$$

Bec se of th charge i dep ndenc f the st ng a l ar te t n the en rgy le ls w ll depend strongly n T but ty sl ghtly on T Th co clu o i i a d with ob e atio wh ch sh ws lose rrespo den es between th energy le el of sob c (o sta t A) ucl

In simila m n it ha p d ful t e-ga d th th k l (–meso s a e pond n the l $T = +1$ 0 –1 (ngle type of leme tary part) th p on whe th v lu s $T = +1$ 0 –1 rr pond to po ti e ne t al and n g t p ns respect vely Thi affo d a o n e i w y f tr ati g th h rg indep den of th t ng ter tion f pi ns with ucl s S ELEMENTARY P RTICLE HYPERON MESO NUCLEAR ST UCTURE SELECTIO RULES (PHYSICS) S MMETRY L WS (PHYSICS) [E L C]

Isotropy (physics)

A body s a d t b sot op c f it phy al p op rt es re t d p ndent upon th d t n th body l ng whi h they a e me ured A body d-play ng sot opy h o ly on ei a t v i d one d lect c n t t, nd on Mo t but n t all l q d a d agg egates m d p of many mall cryst l ra d mly i nt d i p c a e ot op all th p pert es D pend n on their m m t ngl tals may m y not b ot p c th pect t g n p op t F r ampl gl t) with b e tru t e ot p w th espect t lect l re ti ity but n t w th respect t) t d f rm b l ty S ANI OT OPY (PHY I S) FLA T CITY [D T]

Itaconic acid

An organic a id methylene suc i c acid wh ch decompo es at 165 C, ha ing the follow ng truc tural f rmula

```
CH        O
‖        //
C——C
|        \
|         OH
|         O
|        //
H2C——C
          \
           OH
```

Ferm ntati n i a poter tial mi robiolog cal large s ale m thod f r production of th s un aturated branch d ch in d carboxylic acid a a aw ma t rial for c rta n plasti s with special propert es (see FERMENTATION) A m d um consisting of commerci l grade gluc e 15–20% and ino g n c alt s djust d with hydrochlor c acid to pH 1 8–2 0 The pH of the medi m i critic l The medium i culated with p res or mycelium f a elected strain of the filament u a comycetous f ngus, *Asp gillus te reus* i ae at d r ag tated t a st nless teel fermento at 8 35 C, f r 2 5 da s Itac n c a id can also be produced by the u face r tray proce s Th yield is appro imately 40% of th sugar consumed The fre acid is crys-tall zed fr m the filte ed ferm ntat n liquor aft r vacuum o entration a d cool ng [J W F]

Itatartaric acid

An rganic a d d hydroxyita on c a id which has b en p od ed exp riment lly by fermentat on (see FERMENTATIO) Its t uctu al formula is

```
H2C—OH
 |          O
 |         //
HO—C——C
 |         \
 |          OH
 |          O
 |         //
H2C——C
           \
            OH
```

The compo nd s f rmed a a m no p oduct, 5 8% of the total e d iy p odu ed f an itacon c d p odu ng str in f *Aspergillus nig* (ee ITACONIC ACID) The strai i an ult aviol t nd ed n ta t (se MUTATION) Itat rta i id o n s a It d a l cton n app ximately equal qu t t es Se IND STRIAL MICROBIOLOGY [J W F]

Itch

A p ttern f uta o en at n allied to pa n A a i ty f d ffere t t m)—mecha al lect cal hem l and th rmal—may p odu it The most

vivid and persistent itching is associated with path ological skin conditions (prurigo) and with the irritant action of itch powder the spicules of the plant cowhage (cow itch)

The most convincing evidence that itch derives from the operation of the same nervous mechani m as that responsible for pain comes from experi ments on human skin In these experiments a brief train of high voltage sparks imparted to the skin at a rate of five or more per econd each too weak to elicit any sensation ingly may evoke the itching sensation The same timuli at higher intensity yield pain The presumption is that itch is associ ated with a slow but enduring succession of low frequency impulses in the cutaneous nerve fibers leading to the central nervous system from that por tion of the kin Pain of a stronger and more dis agreeable quality results from nervous discharges of higher frequency

In skin rendered irritable by disease or inflamma tion itching may sometimes be evoked by simply touching or stroking it mechanically Temperature changes may produce itch under some conditions However aroused the itch sen ation is a powerful stimulator of action leading promptly to scratching or ome other device to break up the persistent steady pattern of nervous impulses underlying it See PAIN CUTANEOUS [F A C]

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Ixodides

A suborder of the Acarina class Arachnida com prising the ticks Ticks differ from mites their nearest relatives in their larger size and in having a pair of breathing pore or spiracles behind the third or fourth pair of legs They have a gnath osoma (or so called head or capitulum) which consists of a base (basis capituli) a pair of palps and a rigid elongated ventrally toothed hypostome which anchors the parasite to its host They also have a pair of protru ible cutting organs or cheli cerae which permit the insertion of the hypostome The tages in the life cycle are egg larva nymph and adult The larvae have three pairs of leg nymphs and adults four The 600 or so known spe cies are all blood ucking external parasites of vertebrates including amphib ans reptiles birds and mammals

Ticks are divided into three families Argasidae Ixodidae and Nuttalliellidae The la t contai s but one exceedingly rare African species *Nutt ll ella namaqua* which i morphologically intermediate between the Argasidae and the Ixodidae It i of no known imp rtance either medically or economi cally

Argasidae Arga ids or the soft ticks d ffer greatly from ixodid in that the exes are imilar the integument of adults and nymph is leathery and wrinkled there i no dorsal plate or sc tum the gnatho oma is ventral in adults and nymphs but anterior in larvae and the spiracles are small

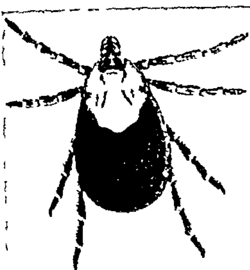


Fg 1 Argas d t k O thodo s o iace s bo t 8 t me aturaI si

and anterior to the hindlegs (Fig 1) The e ticks frequent nests dens and re ting places of their hosts Adults feed intermittently and eggs are laid a few at a time in niches where the female seek shelter Larvae feed for a few minutes to several days then detach and transform to nymphs which feed and molt several times before transforming to adults Nymphs and adults are notably resi tant to starvation some are known to live 10 years or longer without feeding

The family contain about 85 species with 20 in the genus *Argas* and 60 in *Ornithodoros* Se eral are of medical or veterinary importance *Argas persicus* (Oken) the fowl tick is a erious pe t of poultry throughout mo t of the warmer and drier regions of the world Nearly e erywhere it occur it carries fowl spirochetosis a di ea e with a high mortality rate Larvae and nymphs of *Otobius meg nini* the spinose ear tick feed deep in the ears of dome ticated animals in many semiarid regions Heavy infestati ns cau e inten e irritation which lead to unthriftiness and ometimes to death The life history is unusual becau e adults do not feed *O nithodoros moubata* (Murray) transmits relap ing fe er in Ea t Central and South Africa It is a highly dome tic parasite and man is probably the chief host *O turicata* (Duges) *O hermsi* (Whee ler Herm and Meyer) *O talaje* (Guerin Mene ille) and *O rudis* (Kar ch) are important vectors of relapsing fever in the Western Hemi phere a *O tholo ani* (Lal oulbene and Megnin) in Asia The bite of mo t species tl at attack man produce local and y temic reacti n the l ites of ome pe cie especially *O coriaceu* (Koch) of California and Me ico are extremely ven m

Ixodidae In co tra t to arga id Ixod dae ha e a scutum co ering mo t of the d r al surface of the



Fg 2 I odd n k D m I d n f m l bout 15 hm otu l

m le b t only the anter porti n f females nymphs, and l rr e (F g 2) They a e k wn a th h d tick Th are thu m kedly d s- m l r The gn th oma xtend nte ly and the larg p les a e po t r t the h dleg l te d f f eq nti g nest pl ces these tick are lly m or les r domly d tri ted th gho t th h ts en o m nt Larva nymph a d ad lts fe d b t n e d r l days are equ ed f ngorg m nt The mmat e t g f most pec es d p t th gr d f m lti g but thos f th g n B phılus and a few thers m lt the h t The f m le lay a ma s c nt ı g p t 10 000 o m gg The l fe cycl s ally mpl ted ı o t years

The f mily c I f about 11 well d f ed g n ra th 500 pe es Ma y speci tr mit d ea e agents to ma and animals included are ıruses r k tt ae l acteri pr to oa a d to in Trans miss on s by b te r by conta t with crushed tick tıs ues o e creme t Vir s dis a es f man in lude Colo d tick fe er of w stern Un ted States tra s- m tted by *De mace tor a der on* St les and Rus- s n sp ing summer encephal tis and related dis- e Eu pe and Asia tr nsmitt d by *Ixodes pe sulcat s* Sch lz S m imp rtant r ckettsı l d e es f man are R ky M nt in spotted fe er w d ly d t buted in the W tern H mi phe e f wh ch *D nd rso ı D Va bil s* (Say) *Rhipice phalus s nguineus* (Lat ille) d *Amblyomma aj nense* (F br ius) a e important vecto bout nn u le r d elated d ea of the Med terra ea reg on nd Afr a t ansmitted by *R sa gui eus* and some other spec a d Q fever the ag t f wh ch although oc urr ng in many tick thr ugh t th w ld not ommonly t ansmitted dir ctly by them Tularem a (abb t fe er) is a bacte al d e e t a smitted by ev ral species f ticks in the N rth rn Hemi phe e Tick paralys s belie d t be t n au d oc urs in many pa t f the w rld d prod ced by *se eral species of* ti ks during the feed ng p ess.

The ume us t k b ne d s a es of *an m ls* e vast econ mic l sses especially n t opical a d ubtrop c l reg s Examples a babesiasi a pr t zoan d eas caused by species of *Babes a* in cl d g *B b g mi* the ag t of the widely d tr b ted T xas attle f er wh ch t a smitted pr nc pally by sp ies f *B ophilus* East Coast fe e f Afr a n th r proto an d se, c used by *Th l ria p* is c rr ed by e eral sp ies f *Rh p eph lus* A d f m ca ry ng d e se, sev e al pec e ext mely important pest of *m* d an mal Heavy nf t t o of t ks prod ce r m ı l estock and e en de th from l of blood alo *Se* articles pecific d s- *es s al o* ACARI A [c ı k]

J *Jade—Jute*

Jade

A name that may be ppl ed c rrectly to two d t n t m er l Th two t ue jades e j de t and phrit I add t va ety of other mine al are mc rre tly called jade Idocr e i called Cal f rn j de dyed lc te i called Mex c n j de and gr e gr l ite g net s lled Tr svaal t So th Af c n j de The m st widely d trib- ted d a l t kn w tr e type i ephr te the le v l abl f the t Jad te the mo t pr u f gem st nes to the Ch ne e s much are a d m r expe iv

Nephrite Neph te n of the mph bole gr up f rock form g mi er l nd it c u s a ty of omb at of th m ne l t em l t d tr l te Tr m l te s c l m m gne m lum num l te whe e s n r pl c s th m g nes m in a t n l te Although ngle cry tal f the mph bol a fr g le b ca e of two d ec tin f easy le ge the m tely fibr s truc tu e of ph te make t x e d ly d rable It occu r et f l rs m stly f l w ten s ty l d med um d da k g e yell w bla k a d bl e-gr y N phrite h ha d es f 6-6½ on Moh c l a p cific g ty e r 2 95 d r f ct d es f 1 61–1 64 On th r f a t m t ph te gem st n h w a s ngle d x 1 61 N phr t occ th o gho t the w ld importa t so ce cl de R ss N w Z l nd Al ka, e l pr n e of Ch n and n mb r of tates th western U ted St te *Se* AMPHIBOLE GEM

Jadeite Jade te *th m re her hed f the two* j d m al bee l th m i t n e l rs n d pl y It i b t kn w n the l ly i te e gr n col r res mbl g th t f m ald (ed by m ll m t f hr m c o id) I th qu l ty kno n mp ri l jad th m t l s t l t sem t p t Wh t gre nd wh te, l ght ed d h olet bl h let brown a d nge lo lso f u d J d te l h s two d t n of e y cl age, b t a mpa ble a d m fib o stru t e ates xc pt nal t ugh s Al though j de t h be f u d Cal forn a d C tem la, th l impo tant s e f gem q l ity m t ri l es d c red th M g g eg f ppe Burma Th h d e of j d t s 6½–7 it pec fi g ty i pp m t ly 3 34 d t ref ct i es a e r 1 66–1 68 f c tom t ly the l e 1 66 lly e

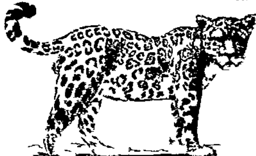
[R T L]

Jadeite

The name given to the mon clin c sod um alum num pyroxe e $NaAl(SiO_3)_2$ J de te f rms green fi b ous cry tals that are col le in th n secti ns a d e h bit the 87 pyro ene (110) cl avage Jade it is rar m tam ph c m ne l f und in some se pe tine masse as ociated with other den e m n erals ch s l ws nit CaAl Si O (OH) gl u cophan g net and othe minerals ch a d p de t em l te serpentine nat ol te (a zeol te) and chl it Beca se f the prese e of albite a d q rt or albite and neph li e mi er l pairs in ome j deite pecimens a d the o gh simil rity of the rock to the ecl g t t i th ught th t jad ite co ld r prese t high p e ur mod fi at n of al b te nd n pheline alb te + ephel n = 2 j de ite Th rea t o has bee prod ced n th labor t ry t 600 C nd 11 kilob rs p e sure or 900 C d at 12 kiloba s p s u e The react n albite = jadeite + qu rt cu s in the laborat y at 600 C t 7 k l b pr s o 900 C at 15 5 kil b rs p e su Attempts t synthe ze j d ite at lower pr ss e h e been n u ce sful Th mi eral s- sociat s n th natural ccurrenc s of jad te d ny the pr se ce f h gh tempe t es J de te c ld be th s d m m neral n the l w r r g n of the arth t Jade t r the f w pl c s wh e t o s cl d Bu m Celebe Cent al Amer c J pa d S Be ito Co nty Calif n Jade te al ed a pe co s to e f r c rv g *S e* GLAUCOPHANE PYROXENE *lso* HIGH PRESSURE PHENO ENA JADE [G W D]

Jaguar

A l g m ore *F lis n* f the f mily Fel d met m s c lled th Am an leopa d Th jagu r i f und f om P tag n a n thwa d t th Un ted



J g F l l gth t 79 in (E L P lm f ld b k f N t l H st ry M G w-H ll 1949)

States border and rarely in Texas Arizona and New Mexico The jaguar may attain a length of 7 ft and may weigh up to 225 lb It is essentially a jungle cat it exhibits great agility in spite of its *size and is able to climb trees and to swim with* facility The jaguar *has been known to kill and eat* humans It may eat almost any moderate sized or large animal including alligators turtles pigs tapirs horses and cattle Jaguars have beautiful valuable fur which is tawny above white below and regularly dotted with black spots most of the spots on the back and sides are open rosettes *See* CARNIVORA [J D B]

Jamming

Intentional generation of interfering signals by powerful transmitters as a countermeasure in tended to block a communication or radar system or to impair its effectiveness appreciably Radio broadcasts or radio messages can be jammed by beaming a more powerful signal on the same fre quency at the area in which reception is to be im paired using carefully selected noise modulation to give maximum impairment of intelligibility of reception When stations on many different fre quencies are to be jammed or when an enemy is changing frequencies to avoid jamming the jam ming transmitter is correspondingly changed in frequency or swept through a range of frequencies over and over again Similar techniques are used at radar frequencies to jam early warning and gun fire control radar systems *See* ELECTRONIC COUN TERMEASURES [J MR]

Japanning

The finishing of metal objects with a black baking varnish that consists primarily of a hard asphalt such as gilsonite Japanning was widely used for metal finishes before the development of modern synthetic enamels This use has largely disap peared because the same properties can be ob tained with finishes based on synthetic resins that are resistant to heat and solvents and are available in a number of colors

The term is sometimes applied to coatings ob tained with Oriental lacquer made from the juice of a sumac tree This al o is no longer widely used *See* LACQUER VARNISH [F SD]

Jasper

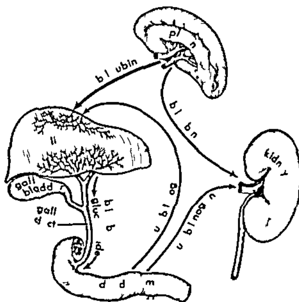
An opaque impure type of massive fine grained quartz that typically has a tile red dark brownish red brown or brownish yellow color The color of the reddish *varieties of jasper is caused* by ad mixed finely divided hematite and that of the browni h types by finely divided goethite Jasper has been used since ancient times as an ornamental *stone* chiefly for inlay work and as a semiprecious gem material Under the microscope jasper gener ally has a fine granular structure but fairly large amounts of fibrous or spherulitic silica also may be present *See* GEM QUARTZ

Jasper has a smooth conchoidal fracture with a dull luster The specific gravity and hardness are variable depending upon particle size and the na ture and amount of the impurities pre ent both *values approach those of quartz.* The color of *jasper often is variegated in banded potted* or orbicular types Heliotrope is a translucent green ish chalcedony containing spots or streaks of opaque red jasper and jasp agate contains bands of chalcedonic silica alternating with ja per Jaspilite is a metamorphic rock compo ed of al ternating layers of jasper with black or red bands of hematite [C FR]

Jaundice

The *yellow staining of the skin* and *mucous* mem branes associated with the accumulation of bile pigments in the blood plasma Bile pigments are the normal result of the metabolism of blood pig ments and are normally excreted from the blood into the bile by the liver An increa e in circulating bile pigments can therefore come about *through* increased breakdown of blood (hemolytic jaun dice) through lack of patency of the bile ducts (obstructive jaundice) through inability or failure of the liver to clear the plasma (parenchymal jaun dice) or through combinations of these *See* GALL BLADDER LIVER

Metabolic pathway A graphic repre entation of the pathway of bile pigment metabolism in the body is shown in the illustration Metabolism of the hemoglobin from destroyed red blood cells is car ried on in organs of the reticuloendothelial system such as the spleen and the resulting bilirubin is liberated to the plasma The pla ma then circulates through the liver where the bilirubin is conjugated enzymatically with glucuronic acid and excreted in the bile Bile travels through the *bile ducts to the* small intestine whence a small *amount of* altered



P thway of blood pigm t m t bol sm

bilirub n, termed r l lnog n m y b e b o bed into the pla ma. Ex es e destructi n of ed bl od cell will cau e accel r ted p odu ti n of bil rub n or l ad the ab l ty f the li er to em the pig ment f m the c rc lati n and produ e jaund c Blockage f the bil ducts will cause elevat on of pla_ma b'lirub n gl cu n d level b c u e f the inabil ty to di p se of thi mat r al i the u ual h n l. Damage t l r ell m y cau ele at on of the pl ma bilirubin o b l rub glucuronide o both, dep d g on th typ and s rity of liv r ll damage

Jaund e occ s whe the le el of the rculat ing p gm ts be m o h gh that they a e i ble in the kin a d m o memb n s whe e they re bo nd by a rea t n which has ot b en ident fied I the n rmal dult t tal b l rubin that is the to tal b'lirr b nd b lirub glucuronide level rar ly ex eed 0 8–1 0 mg/100 ml of pl m wh le j dic ally becomes is ble when total bil ru bin pp ches 1.5 mg Se BILIRUBIN

Hemolytic jaundice De truct n f red blood c lls in th orm l h m n adult p ce ds at a rate m h h bout 0 8% f the ci culati g hemoglob n broke d wn ea h day Thi c b incr d n stat s of x es i e hem ly i up to 10–1 fold w th ut o erta ng the remark ble bil ty of the l ver to l b l rub f m the pl ma E n thi r te f c' n g can be x eeded howev r in cert n m b d t tes i cl d ng ar o s h m lyt nemias hem l es lt ng f m in mp tible blood t ans- f sev r therm l lectr c nj e o nt o- duct n f h m lyt gent nto the bl od st e m S m7 j ndi e oc u s in p lmo ary f cti n

I fa t a d e pec ally p em t re infant th b'l t of th l er to jug te bil rubin with glucur n d is m ch les tha in dults appa tly be se of the l ck f u table nzymes Jau d appears n m ny i f nt h rtly aft b rth then d ppe r with n a few d y with de elopment of th ppr p iate zym tructu I the om m n c t t al hepat dy f n t n th n nmed fect pp rently per i ts nto adult l f The m nal j d c mp ny g eryth obl st fet l (Rh b b es) d t the b l ty f the inf i l e t m tabol e the b li ubin esult g from m rkedly acc le at d hem ly is. S BLOOD C OLRS

Obstructive jaundice Th h ghest le l of t tal b l rub n r e n ch b tru t e j u d m h h pla m lev ls m y r h 50–60 mg/100 ml, and the k may tak n ma k ble d p y ll w h Thi d t n m be br ught bo t thr gh a ty f m n I th inf t th m y be ev m ldevel pm t f th b le d ct uch that o h n l f the fl w of b l ex st hil n the adult b tru t j d e mo t omm nly c ed f y imp t f a g ll t n n the d ts B gn nd m l gn t t m r f th gall bl dd b l d cts p c e lymph odes d b l d t th l s f p t y a d t l d t tr tu e may follow surgery or i flammation in the re gion A s m l r less e e e rever ible picture i seen as a hyper en iti ity esp n e t the adminis- tration f some dr gs the m st common of which r chl rpr mazin and elated drugs and methyl test t rone In the un ommon benign di order known as idiopathic familial jaundice the e ap pears to b decrea ed ab lity to exc te conjug ted bil rub into the bil du ts gi ng ri e t a con stant elevat on in the plasma b lirul n glucu onide whi h is u ually q ite sl ght

Parenchymal jaundice A w de variety of dis- e e e i ts in which part f th jau dice can be a c unted f by a tual damage to liver cells with nse juent dec e e in their abil ty to conjug te bilirub n and excrete the gluc r n de causing an le at n of both fr cti n n the plasma This group omp s s uch ondit ons a inflammations f the li er i cludi g viral l epat ti Weil s dis- ea e syph l s par s tic nfestations and b ct ial nfect n to ic co d ti s in lud ng po s ning with a wide a ety of o gan c and inorg nic com pou d nd i a wide sense the to em s associ ated with ev re sy tem c di eases tum rou co dit n including primary hepat c t mo s a d tho e metast tic f m other org ns and other miscella n u c nd ti ns the mo t c mm n of wh ch is on ge ti e heart failure Some of the e co ditio s ha e an added c mp nent of ob tru t e r hemo- lyt c jaund ce which confus th p ct re f r th l ic an

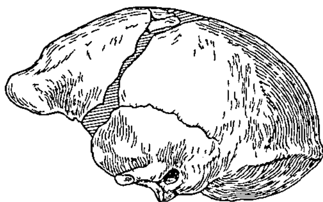
Symptomatology The app ara ce and symptom tol gy f subject suffe i g from j und ce ary f m a t a d pe d ng n the u d l y ng d e e process produci g the jau d e P tients w th hemolyt c jau dic fo in ta ce will u ually ha e n ccompany ng nem a th e w th bstruct e jaund c will c mm nly n te that thei tool are n t brown be a e of la k of b le p gme t (ch l c tool) whil bil rub n glu u de will appe th ur ne d cau e it to t rn dark P ti t w th mal gn n ies will demonst t the u u l s gn of weight los a d a m a wh le tho e with nfl mm t ry o d t ns will c mm nly h fever h lls d pro t at on See PIGMENTATION

[R B H]

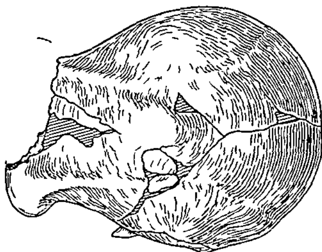
Java man

The most pr miti e know f rm of man and one f th ld t d ti g prob bly from the late lowe a d e ly m ddl Plei t n corre ponding t the F r t I tergl c l and S nd Glacial phas s f th Northern H m ph The fir t pe im disc ed at Tr n l in t al Ja a by Euge e Dubois n 1890–1892, n ted of skull c p femu mandi ble f gm nt and few t eth (the l t n w s- gned t angut n) D boi d cribed these un der th n me P th c th opus e ctus as th fi st e mple f ry primit man th wa m le i a thr p l g l d ry a d d bat Othe k ll p and jaw fragment we fo nd s- oc ated with both th Djeti nd Trin l faun of

Java in 1936–1939 chiefly by G H R von Koenigs wald No implements are known from these beds The thigh bone indistingui hable from that of modern man indicates a fully developed posture for upright walking The brain case is extremely thick with a cranial capacity averaging about 850 cm (modern man 1450 cm³ gorilla 500 cm³)



l t al v w



d s l v w

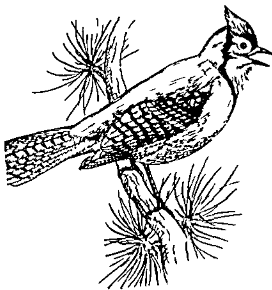
Cran m of P th ca thropus e ctus ll aft von Ko n gswald (Courtesy Ca g I tt t n of W h g t a d i M F A hl y Mo tagu A l t ducto to Phys cal A th pology 2d ed Cha les C Th mas 1951)

The tooth row is long the lower molars totaling 40 mm An exceptional feature is the pre ence of a dia tema (precanine gap) in the upper to th row related in anthropoid ape to the reception of the projecting lower canine thi feature has l een found in no other hominid including Ai stralo pithecus However the canine teeth them el e are not projecting or nonhominid in nature *See* Fo sil MAN [W W H]

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Jay

Any of everal maller members of the family Corvidae differing from other crows in maller ize and in more brilliant plumage Various pe-



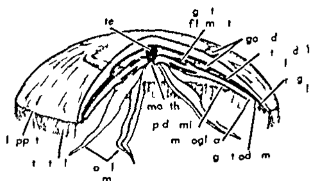
The bluejay *Cyanocitta cristata* length to 12½ in (F om E L Palmer F ldbook of N t ral H story Mc G aw H ll 1949)

cies occur in both North and tropical America and in the Palearctic Most common is the bluejay *Cyanocitta cristata* widely di tributed and abun dant over most of the United States ea t of the Rocky Mountains and especially characteri tic of the eastern deciduous forests The jays are bold noisy bird that usually travel in small flocks They feed upon various seeds berries nut and insects and on nestling birds and bird s eggs *See* CROW PASSERIFORMES [J D B]

Jellyfish

A large group of common marine animals of the phylum Coelenterata mostly of the class Scypho-zoa There are also a few u ually small jellyfi h including a single fresh water species which belong to the class Hydrozoa

The life history of different group varies con siderably In a typical form such as the common jellyfish *Aurelia aurita* the adults are imilar but the exes are eparate The zygote develops into a small ciliated lar a the planula This swims about for a time then ettles to the bottom and trans f rm into a hydroidlike animal the scyphistoma



The jellyf h Au el a a ta d ag ammat c (Fr m T I St o d R L Us g G al Zo logy 3d d McG aw-H ll 1957)

he] tt tt ı a length f b ut 12 mm a d th n nd goes pec l type of m lt pl tr er e ı res ltın a e es f c nected mall nmals c ll d phyra Thes ucerl ke anımal epa at b om f e-s ımm ng (thus mplet ng he a e l tag of p oduct n) d tr sform nt the ad lt, or xual t ge Mo t jell fi hes h a s m l ltern t f g n at ns m t t esis, a h ra terı t of the phyl m

J ll fi h s vary ı ız from G mus ½ ın ın d amet t the gıa t n jelly *Cy a apıl lata*, ıth a dı k p to 7¼ ft ro s te t cl 1?0 ft l g a d h g l t M t jellyfi hes e m h mall r alth gh pe m s 3–4 ft cr ar k wn.

I color the j llyfi he h w w d a ge f m vrt llyn n t be t ful ıdesc t p tel Th r b stru t e mu h l'k that of *Hyd a* (se HYDR) The m uth pe on the unde d f the mbr ll food ı s ızed by the oral arms d q ed by th t gıng lls o emat cy ts lo- c ted these rms d n the f ı ge f t ta le d th bell

Th f esh ate j llyfi h ha be rep ted o ly a few tımes a d f om wıd ly pa ted l calıtıe the U ıted St t s b t when fou d u f few d m l ge mbers It the d appe c m plet ly d m y e r g ı be r c ded fr m that loc l ty Th fo m a d *G mus* c mmo al g the Ea t Coa t of the U ted St tes e hyd o- zo S COELE TERATA METAGENESIS [J D B]

Jet (gemology)

A bl k p qu m t r al that t kes h gh p l h Jet h been u ed f ma y c tu es f rn m t l p po es It a mp ct r ty f l g te l h ha a f ct dex f 1 66 (whı h a o t f r ıs r l t ly h h l t) ha d f 3-4 n M h sc le d p fic gr ty f 1 30–1 35 Jet is mp t nd d abl a d c n b arved or turned n a lathe The p cıpal o c ıs Wh tby E gl d h t occur h rd. b. l Alth gh popular f m Pl y d y u tıl the n e tee th ent ry th e of jet f j welry p rp es h decl ed ma kedly S GEM [R T L.]

Jet flow

A l cal hıgh elo ty stre m a r latıvely stat n ary u r und g fl d Fl ıd may be cau ed to flow ın jet for varı ty of ea s P opul n of a body thr gh a fl ıd may b by jet pr pul ı n l y a propelle or by a p ımp or omp e or The ım pul e wh l u d hydro lectrıc p wer pla ts tak energy fr m a jet f w ter nd con erts ıt nt torq e appl d t a r tat g h ft In fight ng fire m oth jet f water s p od ed by nozzle to rry water t th fir w tho t separ tıng ıt nt d oplets W ter j t re ls u ed t m e rth ı g ld m n g and they a u ed as m ans of dıs ıp tıng fl d e ergy

A jet may be formed by flow o t of a cl d on duıt d wn tr m f om a pr peller Flow through n rıfi e nozzle a es a jet to f rm In the case f pow d elopme t n edle n zzle s u ed to n ert the p e ure a d kı etı e ergy ın the pen to k (p pe l dı g f om th re rv r to the tu bı e) ınt smo th jet of v rı ble dıam ter and d ch ge but p t c lly c n ta t velo ıty (F g 1) The ha g n ı e f jet c ompli hed by movem t of th needle fo w rd b kwa d W th flow thr ugh a nozzl of fixed d ameter a ch nge n d s h ge cau s a rre p d ng h nge ı lo ty f th jet

Th f rmat o of a jet req ı es that a f rce be exerted the fl d n th d ct o f th jet An qu l and oppo te f ce ı e erted n the m ch n ca ı g th j t and th th p p l ı e fo e ın the s of an a pla e or a h p

Wh n j t of lıquıd ue nto a g s s ch a a wat r j t nter g ı t t rb l nc with n the lıqu d nd f ıctı n b tween g s a d l qu d ca se th l q d j t e ntually t p ll ga al ng with ıt

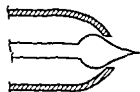


Fıg 1 N dl ı

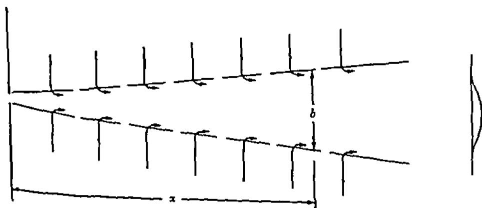


Fig 2 Fl id jet is g t sam fl d m d m

and to allow penetration of the gas into the stream At length the jet breaks into a spray

When a jet issues into fluid of the same den ity fluid is brought or inducted into the jet (Fig 2) The jet spreads at a linear rate with $b = x/8$ Turbulent shear forces reduce the jet velocity within the central cone and equal turbulent hear forces act to increase velocity in the outer portions of the jet The momentum of the jet must remain substantially constant in the axial direction because no forces act external to the jet [V L S]

Jet fuel

Requirements for jet fuels have changed as rapidly as the design of the jet engine In spite of simplicity in principle the specifications are rigid The fuels must ignite easily under all conditions they must burn steadily without blowout or flashback and cleanly with minimal smoking or depositing they must spray well The heat content must be high to minimize the airborne weight of fuel and container the vapor pressure and freezing point must be low

These requirements are met by paraffinic kerosine or by a mixture of kerosine with ga oline fraction so chosen a to keep aromatic content below 25% A typical jet fuel is a ga oline kerosine mixture of boiling range 200–500 F and Reid vapor pressure 2–3 lb See KEROSINE [M SO]

Jet propulsion

The propulsion of a body by means of force resulting from discharge of a fluid jet This driving for e is the reaction to force exerted against the working fluid in giving it momentum in the jet stream Turbojets ramjets and rockets are among the most widely u ed jet propulsion engine

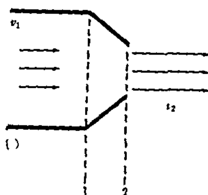
Jet nozzles In each of these propulsion engines a jet nozzle converts potential energy of the working fluid into kinetic energy Hot high pre sure gas e cape through the nozzle expanding in volume as it drops in pressure and temperature thus gaining rearward velocity and momentum This process is governed by the laws of con ervati n of mass energy and momentum and the pressure volume temperature relationships of the ga state equation See FLUID DYNAMICS JET FLOW NOZZLE

For propulsion systems in which the pre ure of the working fluid is not more than approximately twice the ab olute ambient pre ure a converging nozzle is used (Fig 1a) The mass flow from thi nozzle in terms of conditions at sections 1 and 2 is

$$m = A_2\rho_1\sqrt{2gJC_pT_{t1}}\sqrt{\left(\frac{p_2}{p_1}\right)^{2/} - \left(\frac{p_2}{p_1}\right)^{(+1)/\gamma}} \quad (1)$$

and the velocity of the jet leaving the nozzle is

$$v_2 = \sqrt{2gJC_pT_1}\sqrt{1 - \left(\frac{p_2}{p_1}\right)^{(\gamma-1)/\gamma}} \quad ( )$$



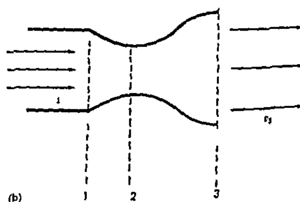


Fig 1 P opuls on nozzles (a) Low p essure converg ng ozzle (b) H gh pressure converg ng-d e g ng nozzle

where m = ma s flow slug/sec
A = cross sectional area ft²
ρ = density slug/ft³
J = work equivalent of heat ft lb/Btu
T = total temperature R
C_p = specif c heat at constant pressure Btu/(F)(lb)
γ = ratio of specific heats
p = static pressure lb/in ²
v = velocity ft/ ec

Maximum flow occurs when

$$p_2 = p_1\left(\frac{2}{\gamma+1}\right)^{/(\gamma-1)} = p \quad (3)$$

This is the critical pres ure at which flow velocity in the nozzle throat i equal to local ound velocity For air and m st combustion gas mixtures

$$p \simeq 0.5p_1$$

For pr pulsion systems in which the working fluid pres ure is high compared to ambient pressure a converging diverging nozzle is used (Fig 1b) In this n zzle the working fluid continues to expand from the critical throat pre sure to ambient pre ure at secti n 3 with a further increa e in velocity beyond the sonic throat velocity

$$v_3 = \sqrt{2gJC\,T_1}\sqrt{1 - \left(\frac{p_3}{p_1}\right)^{(-1)/}} \quad (4)$$

Turbojet. Th turb jet i an a r b eath g propul n e g n u ed in a rcraft Thru t r ting r ge f m a few hund ed to ?0 000 lb r more The engine ope ates be t at high ubs nic or su person fl ght speed wher the high elocity jet a h eves good propul i effic n y *Se* PROPUL ION

The tu boj t h at eng ne (ee BRAYTON CY CLE) Air ent rs the nlet diffu e and i om p essed ad abat cally the e d in the rotat ng com p sso (F'g 2) Heat added by burning fu l t co ta t p es u e the ombu to Th hot ga e pand n the tu bi e which dri s th c mp e s r F rthe p i n thro gh the j t nozzle con erts th rem ng a lable e e gy f the gas st eam int p op l i power (*se* TURBOJET) In ome turbojet m r he t i added i n afte burner f l f g the t rb n to inc e e propul ion p w r o tp t

The i l t d ffuse dec ea e th relat e loc ty f th e t r g r i eas g its pr ure in a p o th r er e f the nozzle e p ns n

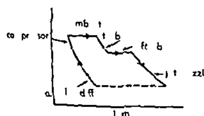


Fig 2 T b j t p e l m d g m

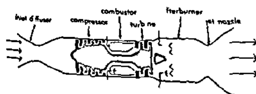


Fig 3 S mpl fi d h m t d g m f t b j t

(Fig 3) Fo supersonic peed a converging d v rging pa s ge is requi ed (*see* SUPERSONIC DIFFUSER) The diffuser th oat area may be va ied mechan cally t match equ rements of va ying flight sp ed

The x al flow comp e so shown has alternate rows of rotating and tat n ry blad s which com p e the air furthe (Fig 4) Th r indi idual ac t n is like th t of an ai pl ne wing in defle ti g th a pas ing o e it They a a rang d so s to c el rate nd decele ate the air alt n tely aus i g a p e u r e t i m ed thro gh th t pe i g annul r pa age betwe n the rotor drum and tat r ca ng

In the combust r jet fuel ke o el ke petro l um fract o is prayed ap r ed and burned Ai f m th c mp e or di cha ge fed into the combust on sp ce th ough l u er n heet metal ombu tio l ners They serve to m x the a r and fuel ap f r ffic nt c mbustion and to cool the line which p te ts the ute c mbu to cas ng from the heat of the fl m

The t rb ne n zzl d ect high velo ity gas t eam against t b e bl des mo ted on wheels Th g s t rned in the blades and by thi m men tum ha g imp ts ergy t the wheel Th may b ev ral t rb ne tag in eng ne co n cted by a d e haft t the compres r (Fig 5)

In th fte bu n r V sect channel are mou ted d wnst am f o n the f l sp ay b Th s ch nnels p oduc ddie in th gas stre m to prom te tabl b rn g nd p e nt blowo t at h gh lt t de A l ered heet m tal l ne protects the afte burne as ng from erbe t ng *Se* AFTERBUR E TURBORAMJET

F r bs fl ght appl at ns a c ergi g jet n zzle f fixed d m ns n i u ed For sup r ni fl ght a c n g g di erg ng j t nozzle is sed Th d m n i f th throat nd e it m be a ed t mat h th req m nt of varying flight p ed d alt tud

A c o e to the gi e re d i en by an ar g m nt of hafts nd gea s tak g power f m

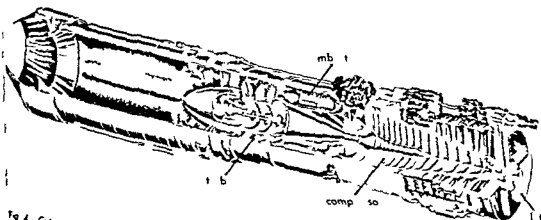


Fig 4 Cutaway iew f J79 t b j t (G l El ct C)

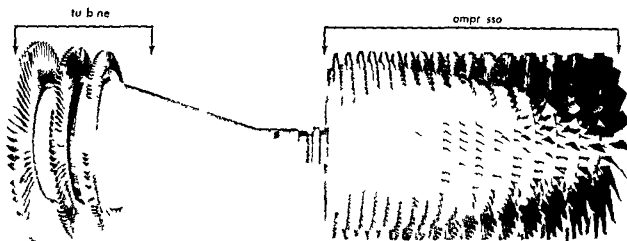


Fig 5 Compressor and turb ne r to s assembled

the compre sor turbine shaft These acces ories in clude fuel and lube oil pumps tachometer and in some installations an electric starter generator

An engine control system en es air pressure and temperature from the inlet diffuser rotor speed and throttle setting It computes from the e by mechanical or electric analog means the required fuel rates and meters fuel flow to the combustor and afterburner The system sen es gas tempera ture entering the turbine and in the afterburner from which it operates to limit fuel rates so as to prevent overheating or over peeding Engine char acteristics repre entative of a modern turbojet are given in Table 1

Table 1 Characteristics of med um sized turbojet

Char cte t cs	W th aft rl	W th ut ft bu n
W ght lt	3 600	2 900
Lengtl n	00	110
D m t r	38	37
Comp ess r st ges	17	17
T b e stag	3	3
Tak ff th t lt	15 500	11 000
Tak -off SFC	0	0 8
Best c u th u t lt	600	500
Best SFC (M h 0 9 at 3 000 ft lt t de)	1 0	0 9
M l t ry tl t lt	6 000	
M l t ry SFC (M ch 0 t 5 000 ft lt t l)	3	

Spec fc fu l co mpt po l f fu l per po d f thr st p h u

Ramjet The ramjet i the simple t air breath ing propul ion ystem and is u ed principally in guided mi ile (Fig 6) It travels at high velo ity compre ing air in it inlet diff i er burning fuel in the air and di charging it through a jet nozzle There are no rotating compre or and turl ine in the ramjet The ram air pre ure rati achieved l y its forward velocity are high enough for efficient operation on the Brayton cycle Howe er the ram jet must be accelerated up to operating peeds b other mean In most missile application thi i accomplished by a rocket powered boo ter tage

Characteristics repre entative of a modern ram jet are

Weight lb	1000
Length in	150
Diameter in	36
Thru t lb	2000
Specific fuel con umption (Mach 4 at 75 000 ft altitude)	2 0

The ramjet is usually designed to crui e within a fairly narrow speed range The coml u tor i imi lar to a turbojet afterl urner with fuel injector V channel flame holders and a louvered lin r f r heat insulation Control and acce orie h u ed in the l ullet nose of the inlet are powered l y a very mall high speed turl ine dri en l y ram air ble l from the inlet *S e* RAMJET *s e also* PULSE JET

Liquid propellant rocket engine The liquid propellant rocket engin is a propul i n y tem u ed to power mi sile and pace vehicle It i u ed primarily t accelerate a load to high vel city and to do thi d li er a large thru t for a rela tively sh rt time interval

Liquid fuel (u ually a hydr carl n re mlling kero ine) and oxidizer (u ually liquid oxygen) are p imped from tank to a fu l inj ctor which pray them int a c ml u ti n chaml er in which they l i rn Th h t ml u ti n g e ape thr ugh a jet nozzle lea ing at v ry high elocity (Fig 4) Tl e reacti n f r e l el ped on n zzle wall a d inje tor head are tran m tte l to tl e l ly f the vehi le Ro ket ehicle re m time st red l y m unting tl e entire engin n giml al

Fuel and oxidiz r pump ha e high p e l cen trif gal impeller dri en tl r gl pe l re l cti n

Fig. 6 C t w y mod l f om t (Ma qu dt A H Co)

ars by a sm ll gle stage g s t rb ne H gh es g s t d v the t b e u lly t ob ed by b rn ng f l and ox di er bl d f om th mp d sch rg to small mbu ti chamber ed g th t th e St rt g ac mpl h d by ım ng thes p pell t f m gas pr s ized ıks. I som rocket eng nes th t b e wo kı g d d comp ed hydrogen p ro ıd *See* PRO-PELLA T ROCKET ENGI E

The effect en f rocket p pellant c mb t ı nd c ted by t theor t l sp ıfic ım

fu l d t bop mp l ı ct comb i h mbe no l

Fig 7 Liquid-propell t ock t g (G l Electric Co)

Table 2. Theoretical v l es f everal fu l-oxidize combi t ons (1000 p i comb st on hambe press e)

Comb ti ns	I_{sp}, ec
Liq d xyg JP1	86
Liq d yg l q d hydrog	388
Hydrogen pero de JP1	66
N_2O UDMH†	274

JP1 k ros l k hydroca bon

† N trogen t tro de-unsymm t cal d m thylhydrazin

pul e F ls a d o d ze s of l w molecul w ight re p efe red bec u e fo a gi n energy rele e nd ma fl w the l ghtw ight molec le a hie e gr at t el ty nd o eque tly h ghest specific mpul e I_{sp}.

Typic l cha acteri tics of a large l qu d propel l nt rock t eng ne ar a follows

P opellant	Liquid oxyg n–JP1
Ch mb r pres ure p	900
Thru t lb	00 000
He ght in	170
N zzle ex t d amet r in	60
O er all I_{sp} ec (t 100 000 ft alt tud)	284
B n t me c	200
Weight (not ı l di g fu l o fuel tank) lb	2000

Solid propellant rocket engine The sol d pro-p ll t o k t e gi p op l ı n sy t m u ed t m il s nd p h l It c n deli la ge th t a d ıs ın ta tly r dy fo pe t *on*

This g c ns ts f a ca ıng filled with a *mı* tu e f prop lla t h m l ın lid f rm Th b rn g ner ti g h t h gh p re g es wh ch es-pe th gh ozzl as h gh el *city* jet c t ng f rward th t r t To teer th eh l me nozzl r c n tru ted so th t th y can b

A large engine such as the first stage of a 1500 mile ballistic missile might have these general characteristics

Propellant	Potassium perchlorate polyurethene and additives
Length in	220
Diameter in	50
Gross weight lb	20 000
Average thrust lb	80 000
Burn time sec	60
Over all I_{sp} sec	230

Propellant combinations are selected to contain as much fuel and oxidizer and as little inert substance as possible As with liquid propellants combinations with low molecular weights are preferred because they result in greater specific impulse for a given energy release The propellant mixture must burn at a relatively slow uniform rate certain inhibitors are added to control this

There are now in use a variety of propellants of two general classes Double base types contain nitrocellulose and nitroglycerin plus additives for stability and to control combustion rates Composite types contain ammonium or potassium perchlorate granules imbedded in a rubberlike hydrocarbon compound *See also* ELECTROMAGNETIC PROPULSION [D C]

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Jet stream

A relatively narrow fast moving wind current flanked by more slowly moving currents Jet streams are observed principally in the zone of prevailing westerlies above the lower troposphere and in most cases reach maximum intensity with regard both to speed and to concentration near the tropopause At a given time the position and intensity of the jet stream may significantly influence aircraft operations because of the great speed of the wind at the jet core and the rapid spatial variation of wind speed in its vicinity Lying in the zone of maximum temperature contrast between cold air masses to the north and warm air masses to the south the position of the jet stream on a given day usually coincide in part with the regions of greatest storminess in the lower troposphere though portions of the jet stream occur over regions which are entirely devoid of cloud

Characteristics The specific characteristics of the jet stream depend upon whether the reference is to a single instantaneous flow pattern or to an averaged circulation pattern such as one averaged with respect to time or averaged with respect both to time and to longitude

If the winter circulation pattern on the Northern Hemisphere is averaged with respect to both time and longitude a westerly jet stream is found at an elevation of about 13 kilometers (km) near latitude 25 The speed of the averaged wind at the jet core is about 148 km/hr (80 knots) In summer this jet is displaced poleward to a position near latitude 42 It is found at an elevation of about 12 km with a maximum speed of about 56 km hr (30 knots) In both seasons a speed equal to one-half the peak value is found approximately 15 of latitude south 20 of latitude north and 5-10 km above and below the location of the jet core itself

If the winter circulation is averaged only with respect to time it is found that both the intensity and the latitude of the westerly jet stream vary from one sector of the Northern Hemisphere to another The most intense portion with a maximum speed of about 185 km/hr (100 knots) lies over the extreme western portion of the North Pacific Ocean at about latitude 22 Lesser maxima of about 157 km/hr (85 knots) are found at latitude 35 over the east coast of North America and at latitude 21 over the eastern Sahara and over the Arabian Sea In summer maxima are found at latitude 46 over the Great Lakes region at latitude 40 over the western Mediterranean Sea and at latitude 35 over the central North Pacific Ocean Peak speeds in these regions range between 74 and 83 km/hr (40 and 45 knots) The degree of concentration of these jet streams as measured by the distance from the core to the position at which the speed is one half the core speed is only slightly greater than the degree of concentration of the jet stream averaged with respect to time and longitude At both seasons and at all longitudes the elevation of these jet streams varies between 11 and 14 km

Variations On individual days there is a considerable latitudinal variability of the jet stream particularly in the western North American and western European sectors It is principally for this reason that the time averaged jet stream is not well defined in these regions There is also a great day to day variability in the intensity of the jet stream throughout the hemisphere On a given winter day speeds in the jet core may exceed 370 km/hr (200 knots) for a distance of several hundred miles along the direction of the wind Lateral wind shears in the direction normal to the jet stream frequently attain values as high as 100 knots per 300 nautical miles (185 km/hr/556 km) to the right of the direction of the jet stream current and as high as 100 knots per 100 nautical miles (185 km/hr/185 km) to the left Vertical shears below and above the jet core are often as large as 20 knots/1000 ft (37 km/305 m)

Daily jet streams are predominantly westerly but northerly southerly and even easterly jet streams may occur in middle or high latitudes when ridges and troughs in the normal westerly current are particularly pr[illegible] or when unusually intense cyclones and anticyclones occur at [illegible]

I suffi e y of d ta on the So thern Hemi pher precludes a d t led de pt on of the jet stream b t t ppea th t the m j r ch ra te tic re em bl quit clo ly tho e f the jet tr m o the N rth rn H m phe The day to-day v riab lity f th j t tre m howe e appea t be le s on the So th n Hemi ph e

It appea that a t t n jet t eam oc u at h gh l ut des both h m phe s in the w t r strato ph re at ele ti n b e 20 km Th dat a a l bl ho e e e n ffi je t t permit th precise locat o det led d s pt on of th phen me *S* AIR MASS AIR WAVES UPPER ST OPTIC ATMOSPHERE GEOSTROPHIC WIND STORM VORTEX. [F S]

Jet velocity

The loc t f th en in exhau t g se r lat e to th e ha t zzle I id al a r b athing y le *it i ass med* th t the ha t g ma ate eq al the i let a r ma rate the ma of fu l b rn d be g n glected nd th t the exha t ga es a ex panded to amb t p e e n th nozzle Und thes e d t the th t of an e g e d re tly pr port n l t th air fl w rate and to th d ff r en e between the j t a d h le eloc t es thru t *i gr test* at zer fl ght peed a d become e hen the fl ght peed is th ame a th jet el ity

Both e gi e p we a d effici y p op t al to the p od ct f th t tim s fl ght l c ty Ther f both pow d ffi n y r ro t zer fl ght speed a d *lso* ero wh flight peed equal j t loc ty B t een the l m t the e is r *of j t* loc ty t fl ght p d th t w ll gi m xim m power and effi n y and jet v lo ty becomes f t th d g f engin e hau t nozzles I ubso c t rbojet jet loc ty an b co tr lled t som t nt by ry ng the p n r f th *h t n zzl* by ny f e l r a ments Th cl m hell is a rly form f ble n zzl I *r mult* ple-l af de g m e tent l ter l pl g ar l u d t ry n zzle a a

I p t e n t bojet w th ft burn a mpl e g t r t le- a f a t nozzl i sed m t t l th t b ne b k p r n th t l p pe th o pt m e fha t j t effi en y f a t bo j t w th t *aft* b rn a a i ble-a nozl may be sed t r g l t t n l ng ne n d tion in th p es e of h t s f fl ght peed g es f lly n l l o e g t d zzles r used t pt e both ternal engn o d t a d jet eff ene

I th a br athi g rock t y l th above mpt d t apply th u t f ock t t d pend t of fl ght *peed R* th at t nt m & thr t d ectly p p ti l t n zzl e jet loc ty plu a p es e tim a a t rm S PROPULSION [H]

Jetty

A artificial b rr er at er mouths and harbor en tra es to deflect and egulat r e fl w and tidal urrent particula ly n rea where littoral d ft au e formation of b rs acro s ha nel entrance J tties re bu lt ngly r n pa rs curved or tra ght t p event l tto al drift acro a ch nnel and to inc ea loc ty f tidal fl w wh h k ep the ch nn l pe J tt are on tru ted to uit natur l c nd t o s and ften re mble b eakwat rs lth ugh lid heet p le walls of t mber c nc te and st l ha e be n u d te i ely A fin exam ple th 4½-m le jetty at th m th of the Columb a Ri e O egon *S* COASTAL ENGINEERING RIVER ENGINEERING [E J Q]

Jig fixture and die design

The pla n ng of t ols for u in maki g prod ctio parts J g po t on p rts for ma h n g operations u h as drilli m lling re ming and bo ng and they phy cally guid the c tt ng tool Fixt res p t on p rt for mach ning welding or as embly op r t n but perm t cutt ng to ls to find thei own p th D es a e tool wh h when m nted in p es pr duc part by punch ng d form ng

Jig and fixture construction F b t d st el st am el e ed after weld and with hard ned t f i rt at th w ar poi t has gen lly per eded ca t gs n jig d fixtur structi n Aluminum and magn ium r sed f m y ap pl ation bec u th y re li hter to handl and le costly to fab cate a d ma hi e Wh n l ge p t are i l *ed uch as tho* *i* a t m bil a c ft indu tr es the epoxy es n f ced w th fib gl otl e *u table mate ial* ca be ed nju t with h d d te l t and bu h g Kirk t nd oth low m lt ng poi t al loy ar *ed wh d fficult co to s m* st h d pl ated

Loc ti g meth d Th acc ac s *obta* ed by j g fixt es r d p nd t p the acc y w th wh ch *pa ts b* t ntly p t ned th fi t and ub qu nt j g *o fixt re* The di m n l cons t e f the part tself f ct O e de ble p act t b *e the fi t j g* fix tu e a e *s of op t s* *eate lo t g p* t n th part n th form f m lled rf s or h l wh h c n be ed n b *equent op r ti* Th m l t ng p t h ld be u ed f s many ope t n a p ible

Cl mp g m y d form th p rt if the loc ting p ts r ot le ted d a t geou ly Lo ting po t h uld b p ed fa part s th p rt d n p m t d be s m ll a p bl n d *ing the n ed f* dequate upp t and nt p ted w *Th e b tt* ns or mall pad dete m ne pla a d *top* p d t rm e loc t ns w th n th t pl e (Fig 1)

Th u f two r m e tr ight p s n t d is bl f loc t g f m h les bec u e light di me i l r t n b twe h les w ll m k t dif

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Length in	220
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If the winter circulation is averaged only wit[h] respect to time it is found that both the inten[sity] and the latitude of the westerly jet stream var[y] from one sector of the Northern Hemisphere t[o] another The most intense portion with a maximu[m] speed of about 185 km/hr (100 knots) lies ove[r] the extreme western portion of the North Pacifi[c] Ocean at about latitude 22 Lesser maxima o[f] about 157 km/hr (85 knots) are found at lat[i]tude 35 over the east coast of North America an[d] at latitude 21 over the eastern Sahara and ove[r] the Arabian Sea In summer maxima are found a[t] latitude 46 over the Great Lakes region at latitud[e] 40 over the western Mediterranean Sea and at lati[tude] 35 over the central North Pacific Ocean Peak speeds in these regions range between 7[4] and 83 km/hr (40 and 45 knots) The degree of concentration of these jet streams as measured b[y] the distance from the core to the position at which the speed is one half the core speed is only slightl[y] greater than the degree of concentration of the jet stream averaged with respect to time and longitude At both seasons and at all longitudes the elevation of these jet streams varies between 11 and 13 km

Variations On individual days there is a c[onsid]erable latitudinal variability of the jet stream par[ticularly] in the western North American and west[ern] European sectors It is principally for this rea[son] that the time averaged jet stream is not well defined in these regions There is also a great day to day variability in the intensity of the jet stream throughout the hemisphere On a given winter day speed in the jet core may exceed 3[7]0 km/hr (200 knots) for a distance of several hundred miles along the direction of the wind Lateral wind shear in the direction normal to the jet stream frequently attain values as high as 100 knots per 300 nautical miles (185 km/hr/556 km) to the right of the direction of the jet stream current and as high as 100 knots per 100 nautical miles (185 km/hr/185 km) to the left Vertical shears below and above the jet core are often as large as 20 knots/1000 ft (37 km/30 m)

Daily jet streams are predominantly westerly but northerly southerly and even easterly jet streams may occur in middle or high latitudes when ridges and troughs in the normal westerly current are particularly pronounced or when unusually intense cyclones and anticyclones occur at upper levels

In ffi ie cy of d ta o th Southern Hem spher p eel d a d ta led d ctipt n f the j t tr am b t it ppea s th t the majo ha acte istic r m ble q te el ely th f the j t tre m on the N rth rn H m phere The day to-day variabil ty of the jet tream h e e appear to b les o the Southern Hem ph re

It appe rs that an te se j t t am c u t h gh lat tude on both hemi ph re i th w nt r t atosph re at elevat ns above 20 km The dat a a labl h e re i uffic nt t perm t the prec se locat o or deta l d de c pt on of th ph me n *See* AIR MASS AIR WAVES UPPER SYNOPTIC ATMOSPHERE GEOSTROPHIC WI D STORM VORTEX [F S]

Jet velocity

Th loc ty of the g e exh t ga e r lati e to the hau t zzle In de l a b athi g cycl it s a umed th t the xh t gas mas ate eq al th inl t a r m s r t th m s f fu l b n d be ng glected nd that th e hau t ga es e ex panded t mb t p es u i the nozzl Und r these d t the thru t f an eng e d re tly proport n l t the fl w rate a d to the diff r ence bet ee th jet d h cle eloc ties th t i gre test at ze o flight spe d and b mes hen th fl ght speed s the s me th jet v l c ity

Both e g ne pow d effi ien y a p op r t l t the produ t f thru t t m fl ght v loc ty Th *f e* both p er and fficie y a e r t zer fl ght peed a d also z wh n fl ght p d eq al j t loc ty Between these l mit th i r u of j t veloc ty t fl ght p d th t w ll g e m x mum p w a d fficie y d j t el ty becomes fa t in the de g of e g xhau t nozzles I bson t bojet j t lo ty can be t t lled t some xt t by ary g the op n a a f the e h u t ozzle by any of eral range ments *Th* clam h ll i n e ly form f abl n zle I mult ple-l af de gns a m ent Int rn l plug al u ed t ary zzl re

I p a ti e n t b jet with aft b rn a mple co ergent va ble a ha t n zzl sed m t nt l the turb ba k p re i th t *p pe th n t* pt m z e h u t j t eff y fa t bojet w th t fterb ne ble- re n zzle m *be u ed t* guf t int al g ne d tio t th p es f s ch ar at f fl ght d t as t m h ng lt t d O personic ng f lly ble n e ge t d gent zzles re u ed t ptim both t rn l eng n d t d j t effi n y

I th n br th ng ock t y l the abo mpt d *n t* pply th i t f ock t i d pend t l fl ght peed R th t t t m l ast loc ty pl p es t m t m S PA VCL I

[H]

Jetty

An art fi ial b ri r t iver m th a d harbor n tr c s t defl ct and reg l te ri r flow and tidal currents p rt ula ly in reas where l ttoral d ft c u es formation of bars ac chan el entra ce Jetties a e l ult ingly o i pairs curv d or t ight to prevent l tto al dr ft acr s cha nel a d t incr as velo ty f tid l fl w which keep the chann l pen J tt s re con t ucted to uit natural cond tio a d ften r embl breakwat rs altho gh s l d he t pile wall of timber c c te a d te l h e be n u ed e ten ely A fine ex m ple is the 4½-m le jetty t the mouth f the Columb R e O eg *S e* COASTAL ENGI EER ING RIVER E GI EERING [E J Q]

Jig fixture and die design

The pl nn g of tools fo u e in m king production parts Jigs po it on part fo mach ni g p atio s h d lli g m lling r m g and bo i g and they phys ally guide the cutt ng t ols Fixt es p sit p t fo mach ing weld ng r as embly pe at ns but permit cutt ng t ol to find thei wn path Dies are tool wh ch when mo nted in a p es prod ce p rt by p ch g a d f rmi g

Jig and fixture construction Fabric ted t el tr rel ed afte w ld g d w th hardened teel sert at th w ar po t h g erally super eded ast n s jig and fi ture c t ct on Alumi m and mag e um are u d f m ny p- pli t ns be s th y a e l ghter t ha dle and l ss c tly t f b icate nd m ch n When la ge part r n l d uch a th e n t m b l o raft du tr es th poxy resins reinforced with fil e gla tl e u table mat l can b u ed in c ju ct n with h dened st l n t a d bu h s K k t nd oth l w melting poi t al loys r u ed wh r d ffic lt t u mu t be du pli ted

L an g meth d Th ac u cies bta ned by jig fi tu es a d r e de t upo the a u cy with whi h part a b c n t ntly p it ned in the fi t d ub q nt jig fi t r The d n n l e te of th *j art it If* is fact On d s bl pr ct i t h th fi t jig r fi tur n er es f p at t l cati g p ts on th pa t n the f m f m lled f ce r h le which a b d i b qt t pe at Th same loc ti g p ts ho ld be ed fo a many p rat a p ble

Cl p g m y def rm the part f the lo t ng p ts re t l t d d t geo ly Lo t ng p ts h uld b p ed s f apa t s the part design p m t d be a m ll s po bl d er ng th need f deq at pp t nd ant p t d we Th e butt r m ll p d det rm ne a plan a d top o p n d te min loc ti w th n th t pl ne (Fig 1)

Th f two m e t a ght p t d s bl f lo ting f om h les b ca l ght d m l t betw en h les w ll m k t d f

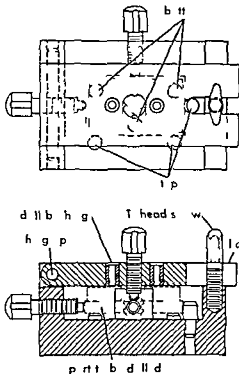


Fig 1 Buttons and stops locate pa t in dr ll j g

ficult to load or unload the part The most common method is to use one round pin and one diamond or elliptical pin (Fig 2)

Self centering devices must be u ed when it is necessary to locate centrally from two surfaces that can vary When locating round parts it is prefera ble to work from hardened V shaped locators The angle of the V should be 90 Sight holes should be provided to permit the operator to ob erve vis ually whether or not the part is down on stops and l uttons Where practical multiple station jigs and fixtures should be made in such a way that parts can be loaded while others are being ma chined The cost of loading or unloading parts is often greater than the machining co t

Clamping The clamping arrangement hould be simple Clamping pre ure is applied over or be tween the pads or buttons and standard vi es are adapted as machining fixtures where practical Ma chining is done toward the fixed jaw Standard air cylinder are u ed If more than three supports in one plane are nece ary all in exce s of three hould be adju table Where a wrench mu t l e u ed all nuts should be standardized Large hand knol s ensure ea e of operation and cam type clamps are usually faster and more positive than other meth od

Tool guides In jig tool guide con i t of l u h ing that guide drill reamers and boring bars American Standard A ociati n ize sl ould be u ed when po ible Bu hing n rmally extend a clo e to the part a practical to a ure accuracy of hole location and to eliminate chip tangle within the jig

The u e of slip-remo al le l u hing in har lened liner permit econdary operation such as tap ping reaming and counterboring Where accuracy demands reamers may al o be guided in lip bu h ings either by pilot or by their cutting edges

Tool guides in fixture are limited to et pieces for e tablishing a relation hip between the cutting tools and the fixture The e are permanently located on the fixture and clearance i allowed between the set pieces and the cutting tools A feeler gage the thickne s of the clearance i then u ed to locate and et the cutting tools

Chip control During drilling chips are either brought out through the bu hing by allowing zero clearance between the bu hing and the part or per mitted to stay in the jig by allowing ufficient clearance for that purpo e The former method is the more desirable but if tolerances are not criti cal and the chips are di continuou wear on the bushings can be reduced by the latter method To compromi e between zero and ample clearance create the disadvantages of both with none of their advantages

Jigs and fixtures are designed with ufficient openings for chips to be removed by gravity cool ant flow brush or air bla t Du t collectors are used to collect dry grinding chip or chips of non metallic or toxic materials

Safety Practice dictates the u e of ½–13-in or larger tapped holes for eyebolts in all jigs or fix tures weighing 50 lb or more and the removal of all sharp corners that could injure operators

Stamping dies Die produce parts either by tressing the part material in hear until fracture occurs or by stre sing the part material beyond the yield point where it takes a permanent et but not beyond the rupture point where it breaks Dies using the former method include l lanking piercing cut off and lancing dies and tho e employing the latter method include drawing bending embo ing

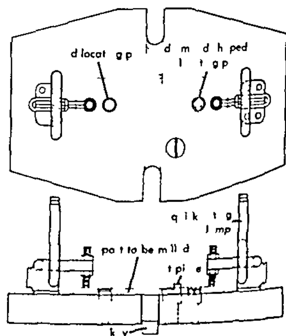


Fig 2 Ro nd pin po d w th diam d pi locat i part a d allows part to be loaded e dly l m ll g f i e

Fig. 3 P g ess ve d p rf rm ev l p t sequen lly mat rial adva from first to ec d punch betwee strokes.

and f rming dies Any p actic l comb nat n of the ... th per ti be in l ded in o d, and can be perf rmed ith m ltaneou ly o m st ps u in a pr gres ive-type d e (F g 3)

Di nstructi Con e t n l t mp d es are composed f th f ll wi g main parts the d set, co tin f t p and bott m hoes gu d pi ad b hi gs the pun h, whi h s th male cutt g r f rming member th d whi h s the femal cutting o f rm g member trippers that emov th p rt from th p h d e gages t loc te the p rt part m terial a d bl nk h lders that remov wri kles nd e a even fl w of material m d. wing (F g 4)

Di s l cti The d type elected fo a j b determined by p rt des gn d eco m co d ra tions, h as th umber of p eces t be prod ed, cost f alternat methods of p oduct on, and ma n tena f th tool tself

Very l w ctivit es l be l part tole nces of te) tity pec l types f d es s h teel rul d es plow teel d es f r cutti g pe ati n a d pla ti rubb dies f r f rm g per ti Most urat m l ing mode t t h gh ctiv t es d es empl y g h dened tool teel

La g ctivit es m t mes j t fy th high cost f d es m d f m tu g ten a b d Well-de gned d ll b ilt t gsten carb de dies c n turn out a la g l m f e t mely cu t part at h gh peeds w th littl h pening pai

Mat rials f t mping A m teri l softer t a th pun h and d d which will n t h tter h impact m y be cut, p e ed bl ked in d. l d g be di g a d f rm g per t o d rtil t s the p m equ t Spri gb k d d orm tio s, lud g ha ges in m teri l th k ess occurri g d ri g the f rm g pe ti n, a takes int en d t n. M t rial t ed ther d idually h ed p eces trip co l f rm. S p or coiled mat ri l m kes pos bl the se f ... feed g mech m w th es lt t l bor economies not u ally p s t al w th h ared ma terial les a f lly t m ted set p prov ded.

pi g tol Obt bl es a l d m r ge d pending on th p rt mate al, th ck es f tock bei g pun hed, izes and part co figur t n, and th p xim ty of bend or h les A cu c es of ±0 0005 in are obtainabl n thin m t ri l ng compound type dies h wever under n rm l pe ti g co diti n practical t ler nces l ght m teri l can be expected t ary f m ±0 002 n. t ±0 010 in d on h vy m te ri l f m 0 010 in. t 0 030 n T a d d t rti n, h les ar pl ed d t c no les than th material th ckness from th ed f an ther h l and no les th three times th mat ri l thickness fr m a be d r d us H l locat n establ hed

Fig 4 Main p rts f nve ti l stamp g dies. ( ) F pie ing (b) F bla ki g and drawing

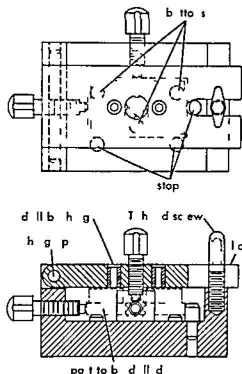


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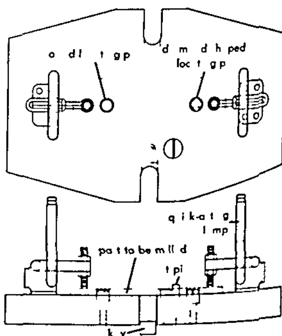
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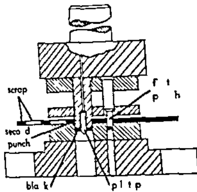
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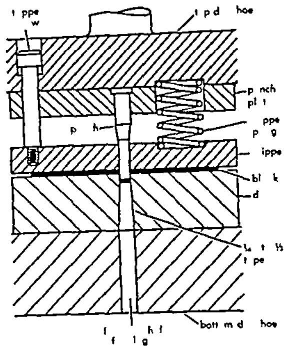
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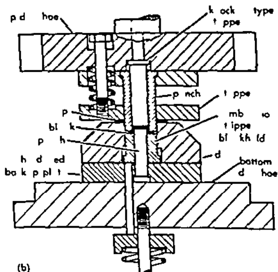


F g 2 Ro d pin pai ed with d mo d pi locates pa t a d allow part to b loaded readly i m ll g f t



Fg 3 P og ess d p rf m l p t seq lly m t l d c f m frst t d p ch betw st k





Fg 4 M n p rt f t l t mp g d ( ) F p g (b) F bl k g d d w g

and forming d Any pr ti l comb natio f tl above r oth perat an be ncl d d e de and a be p formed e the m ltaneou l r m t ps u g p ogre e-t pe d e (F g 3)

D nst u t Co e t al tamp ng d e ar mposed f the f ll w g ma p rt th d e set, c tung f t p a d bott m hoe gu de p n a d b h gs th p ch which i th male utt ng r f rmi g m mber the d wh ch the f m le uttmg r f rm g memb t ipp th t rem e th p rt f om the p ch d e g ges to locat th part o p rt mat r al and bl nk h lde th t re- m ri kle d ca e e flow of mat ri l m d awing (F g 4)

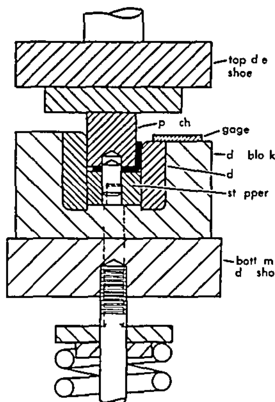
Di l ct Th d type l ted f a j b i d t rmined b p t d gn d e om id ra ti ns, h th n mber f p eces t b p odu ed t f alt rnat m thod f p od ctio a d m n ten l th tool t elf

V ry l w t vit l be l part t le n f ten j t fy p l types f d es h teel le d es o pl w st el d es f r cutt g per t on a d pl t bb d es f f m g pe t ns Mo t ppl to t ol i g m d at t h gh a t t qu d e empl y g h de ed tool teel

La ge ct it ca met mes ju tifv the h gh cost f d m d f m t g t carb d Well de gned a d ll b lt t gste c b d d an t m t l g l me f t m lv c t part t h gh sp ed w th l ttle ha peni g pai

Mat rial f t mp g A y m t i l fter th the p h a d d d wh ch w ll not hatt th mp t m y h t p d bl nked n d l d a g b d g and f rmi g op ti n d ctil ty i th p m q t Sp gb k a d d l rm t i l d ng h nge n mater al thi k es or ri g d g th f rm g p ti a e tak i t de ti Mat l u d th r i md d lly h ed p n tr p r l f rm St p c led m t r l m ke p bl th f a io feed ng mech m w th lt t lab r ec m n t u lly p ct c l w th h d m ten l les f lly t m ted t p s p d d

St mp g t l c Obt ble u b d r ng d pe d g th p rt m te l th kne of t k be ng pu ched s zes nd part nfigu ti n d the p m ty f be d r hole Ac es of ±0 0005 e bt inable on th n materi l ing mp nd type d howev un der n mal p t ng co dition pr tical t ler on l ght mate l c n be e p ted to ary f m ±0 002 to ±0 010 d n h y m te l f om 0 010 in to 0 035 i T d d st rt n hole pla ed a d t e le th n th m t l thick f m th edg of th h le d le th n th t mes the m t ial thi kn s f m b d du H l l t e t bl hed p e-

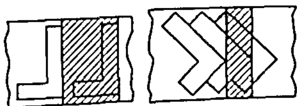


Fg 5 Bend ng d e showing ad quote clearance be twee hole and bend

vious to bending operations are subject to material thickne s tolerances and the stretch of the mate rial which occurs during the bending operations (Fig 5)

General design A tool lineup is made to deter mine the equence of operations and the type and number of dies required to complete the part or blank A blank layout i made to obtain optimum material u age and to reduce crap (Fig 6) and the material is checked to make ure the l urr i on an acceptable side of the l lank Material i normally fed into the die from right to left or front to back When tolerances permit the fini hed edge of the tock can be u ed as a side of the blank

Tonnage to hear or form is computed and the die i designed for a pre that will l andle thi ca pacity It is generally po sible to impro e die life by u ing a press rated for twice the required ca pacity Work can l e performed on pre es of le s than the computed capacity by staggering the lengths of punche or l y adding shear t the punch or die Safety requires that tapped hole l e pro



Fg 6 Bl k layo t compa amo t of m te ial

vided for eyebolts in dies 50 lb or more in weight and that afety bolts be provided to hold the d e together when not in use Guards and undercuts are applied to dies to protect the hands of the oper ator Standard punches and die inserts for rou d, oblong square or rectangular holes can be pur cha ed in small increments of ize and are read ly available for replacement when breakage occurs. *See* MACHINING OPERATIONS METAL FORMING SHEET METAL FORMING [R L C.]

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Johne s disease

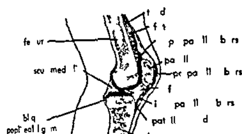
A specific enteriti or inflammation of the ga tro inte tinal tract of cattle heep and deer caused b the bacterium *Mycobacterium paratuberculosis* The di ea e is pread by animals having eaten the droppings of sick animal and is diagno ed by the clinical symptom the pre ence of *M para tuberculosis* in the droppings and l y a po itive kin reaction to johnin a preparation imilar to tuber culin *M paratuberculosis* i a hort thick acid fa t rod which can be artificially cultivated only on media containing a sub tance or ub tances a yet unidentified pre ent in extracts of acid fa t bacilli and of certain plant The di ea e has an incuba tion period of a year or more Sick animal ha e intermittent diarrhea without fever and grad ally become emaciated The muco a of the mall intes tine hows gro s thickening and the mesenteric lymph nodes enlarge without ulcerati n Ca eatv a (death of ti ue with change to a chee elike con si tency) and calcification do not occur The drugs treptomycin viomycin 4 4 diamin ulfone and i onicotinic acid hydrazide although u ed suc ce fully in the treatment of tul erculo i have l een u ed without ucce s in the treatment of Johne s di ea e Animal that have Johne s di ea e mu t be de troyed l ecau e they rarely recover and pre ent a focus of infection for other animals in tl e herd See TUBERCULOSIS [C.H M]

Joint (anatomical)

The region or point of contact l etween l ony sur face al o known a an articulati n There are three general types of articulation the synarthro i or imm val le the amphiarthro i or slightly m al le an l the diarthro i or freely moval le

Synarthro e include tho e immo al le j ints wl ere the l ony surfa e are fixed l ut u ually sep rated ligl tly l y a mall amount of fil ro i ti u r cartilage The e include the utures f the skull and th ty e kn wn a ynch ndro i where a p ece of cartilag act a a tempc rary form of artic la ti n The latter c ndition i se n in childr n bef re tl e cartilag i c n erted int tl bone of ad lt l f Otl r pecial form of ynartl ro i occ r such a g mph i tl e in erti n of tl e te th into the bony socket or al e li of the jaw

In the ligl tly mo al l r amphiartl r tic j ints the pp ing bony urfaces ar parat d l y a flat tened artilagin u di k oft n of rather c mpl x



lat l w f k ; t (F m N L H d A O l d Bl k st N w G ld M d l D ct ry 2d ed Bl k st 1956)

t b l art l t s d the ligame t att h me t b t e the t b and th fibula at the ankl

D arthro es r ma ked by a syn i l memb e h h l rm cl ed bout the opposing bo es I ddit the d f the b es are ed with pe l d f m f rt l t g cartilage d pted f m me t. The fl d of th vn ial j int a t s a lub c t Th e may lso be a ar ticular di k b t e the two pr c pal s rfa s to ct as a f th a d to m me t

Th d arth se e n med c rd g t th type of m t n n l ed n them The hi g j t or gi glym s p rmits m t ly n one pl ne th fi g k e d lb w j ts e e mple The p t j int, r t och d e t cted t a r tat on f bo b t a the Th t t of the atlas bo t the x s, s cond rv l v teb a typ e l. Th ball d ock t j t, or e a th os s hara t t of the h p d h uld art l t m h h wid ra e f m t ll pl es is p bl Cl d j ts o rth od p rm t nly est ct d m ti n b twee c c a d a ex f Th type u ome f th wr t nd kl bo rt l t n *S* ANKLE WRIST

Co dyl d rt lat o f rm d by an d s f e wh h fits t ll pt l ty that all m ements pt t t p rm tted Th wr t j int i an mpl f thi typ

Th t p of m ti p rm tted by o s j ts m b t t d t n k d f m m t m y be mb n t dep d ng th l ti a d d l pm nt l f tu I dd t rt in d d l h w a wid r g f m t n th th p rt la l f j t m lf rmed di d In m t j int f th m bl typ th a d fi nt rra g m t f t g t c l l g m t h h f h t gth nd pp t *S* MUSCULAR SYSTEM SKELETAL SYSTEM

[E G S T]

Joint (anatomical) disorders

Local o g lized d t wh h ff t th j nts nd el ted t u Ab t e p 25 h m f rm f j t d t b c Th most m m n ar form f rth t s, nfl mm t f j t stru tures. Th e may f ll w sp cific f t njury g lized d a t t d g ne t e h nges hi h l g ly p llel the ag g p in th body

The arthritis of rheumatic fever is fairly charac teristic in that joint in ol ement is usually migra tory and coincides with the clinical state Although the exact cause is unknown a form of hypersensi ti ity to a prior treptococcal infection is appar ently contributory

Rheum to d arthritis one of the mo t common di eases which in l es j ints is also of unkn wn etiol gy but agai hypersen itivity is related as well as oth r factors It occurs mo t often in yo ng or middle aged adult and ha a m rked tendency t de go p t e rem n Multiple joints a e i ol ed pec ally th e of the sm ll bone in the hands feet, wri ts r jaw In many affected p there i a clo e correlati n b tween symptoms and m t nal t te

Oth r so-called coll gen di ea es such a lupus eryth m to a d periarterit od a freque tly are accompanied by a th itis much l ke the rhe m to d var ty

Degenerati e j int di e e is most c mmon in old r people The maj r form steoarthr ti is m ked by d te ration f the articular rfaces of the we ght beari g joints of the knee hip and spin The end f the fi ge s are often invol ed

Arthrit m y be produc d by t auma u ta ned f m a ingle ti s -damag g i jury from re p t d phy l i sult to a p rti lar j int

I fecti arthr t s may be ca ed by g norrhea r in on l y pne mococ t eptococ i a d othe p th g ic o g ni ms Special form more chr c in ture are ee n t berculos a d syph lis

Gout s an e mpl f arthrit s ca sed by meta b l c d ord I this i ta ce there is n abn r m l ty f p ine b eakd wn that produc accumu l t of r c a d a d ur tes in j int ti es The phy cal fi di gs and cl ical c ur are u lly d t ti

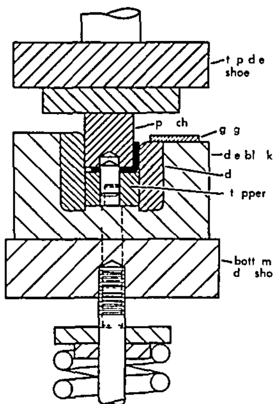
J nt d ord s m y be f nd i certai n rv us sy t m d ase pa ticul rly th se wh ch affect the p l c d Sy i gomyelia syph lis (tabes d r a l) d l p y a e e mple in wh ch de tr ct e j i t le o m y be ec d ry to nerve d m ge *S* LEPROSY

Ma y sy tem d e es of unknown or q ite dif f t t ol gy may pr d e me form f rth it s j i t d g at n Hem phil a h red tary blo d d o d crom g ly n e do rine dysfunc t n d Ray a d s d e e a di ea e f bl od ves l a mpl wh h di t the d ty

Lo l d t rb e e th *p cific r n pe fi* m y l l d t j i t l ement The e incl de b t t n yn ti formati n of y t in the y m d th r co d ti

T m s f j t t a e us ally b gn chon d m fibr m d l p ma but th m l g ant y o o r m not e

Rh m ti m p fi p ed mina tly l y t m wh h l des l c l p i a d t de e s M t a se ch c inflamm t s r mildly p gre v d g t n nd many when esti g t d fall to one of th



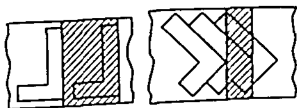
F g 5 Bend ng d e showing ad q ate clea anc be tween hole and bend

vious to bending operations are subject to material thickne s tolerances and the tretch of the mate rial which occurs during the bending operation (Fig 5)

General design A tool lineup is made to deter mine the equence of operations and the type and numl er of dies required to complete the part or blank A l lank layout is made to ol tain optimum material u age and to reduce scrap (Fig 6) and the material is checked to make sure the burr i on an acceptable ide of the l lank Material i normally fed into the die from right to left or front to l ack When tolerances permit the fini hed edge of the tock can l e used as a ide of the blank

Tonnage to hear or form is c mputed and tl e die i de igned for a pre s that will handle this ca pacity It is generally po sible to improve die life l y u ing a pre s rated f r twice the required ca pacity Work can l e performed on pre e of le than the computed capacity by staggering the lengths of punche r l y adding shear to tl e punch or die Safety require that tapped h les be pro vided for eyebolts in dies 50 lb or more in weigh and that safety bolts be provided to hold the die together when not in use Guards and undercuts are applied to dies to protect the hands of the oper ator Standard punches and die inserts for round, oblong quare or rectangular holes can be pur cha ed in mall increments of size and are read ly available for replacement when breakage occurs *See* MACHINING OPERATIONS METAL FORMING SHEET METAL FORMING [R L C]

Bibliography F Wil on (ed) *Tool Engineer s Handbook* 1949



F g 6 Blank layo t compar amo t of mat ial sed to p od ce o e blo k (shaded port on) by two d ff r t de po to s

Johne s disease

A pecific enteriti or inflammation of the ga tro intestinal tract of cattle heep and deer cau ed by the bacterium *Mycobacterium paratuberculos s* The di ea e is pread by animals having eaten the droppings of ick animal and is diagno ed by the clinical symptom the pre ence of *M pa a tuberculosis* in the droppings and by a po iti e kin reaction to johnin a preparation imilar to tuber culin *M paratuberculosis* i a hort thick acid fa rod which can be artificially cultivated onl on media containing a sub tance or ub tance a ye unidentified pre ent in extracts of acid fa t bacill and of certain plant The di ea e has an incuba tion period of a year or more Sick animal ha intermittent diarrhea without fever and graduall become emaciated The muco a of the mall inte tine shows gross thickening and the mesenteri lymph node enlarge without ulcerati n Ca eati (death of ti ue with change to a chee elike c n i tency) and calcification do not occur Th drugs streptomycin viomycin 4 4 diamino ulf n and i onicotinic acid hydrazide although u ed suc ce fully in the treatment of tul ercul i ha been used without ucce s in the treatment o Johne s di ea e Animals that have Johne di ea mu t be de troyed becau e tl ey rarely reco er an present a focus f infection for other animal i the herd *See* TUBERCULO I [C H M

Joint (anatomical)

Tl e region or point of contact l etween bony sur fa e al o known a an articulation There are thre general types of articulation the synarthro i o immo al le the amphiarthro i or slightly m al le and the diarthro is or freely m val le

Synarthro e include tho e immo al le j int where the l ny urfaces are fixed l ut u ually sepa rat d lightly l y a mall am unt of fil ro i ti u o cartilage Tl e includ the s iture of the sk l and the typ kn wn a ynchondr i where a p ec of artilag a t a a temporary form of arti ul ti n Tl e latt r conditi n i seen in cl il lren bef r the cartilag i c n erted into tl e bone of ad lt lif Otl er pe i l form f ynarthro i occur such a gomph i th inserti n of th teeth i to the bon so ket or al olt of th jaw

In th ligl tly m al l or amphiarthrotic j int tl oppo ing bony surfa e are eparated l y a fla t n d artilagin u disk oft n of rather c mple tructur C mm n exampl includ tl e inter

\ rth Temperate zo e b t al o r Central America o th Ame ca trop l A a J a and New Cuine Th y are decid s mo oec o tree l rul th altern te pi t ly comp d ar mat c es. The fl rs ha e a p m t perianth a d h t m ate fl wers a bo n catkin In m t pec es of h k ry (*Carya*) and walnut (*J glans*) h f ut i a drupel ke n t h g deh cent or deh ce t leathery or fibr t s hu k Econ m cally hese trees ar mpo t t b c u tl y ipply valu ble timb nd n t h g del fla r *See* HICKORY WALNUT s e lso DICOTYLEDONEAE EMB YOPHYTA PLANT KI GDOM TREE

[P D S]

Junco

A y f everal pec es of N rth Am a p r w f th gen s *J co* f mily F g llidae Tl e e d are m ll th th E gl h pa w are rth t tr k r t ip and a e predomi t l gray bo e nd l ht g y to wl iti h bel w Some pecies h bl ck he d th s gra he ds ome i m ked th r sty red n th back th by i p k b d l g th de j t bel w the w g They r all ea ly gniz d by the d t n tly ht ut t l f th wh h th y flash fl ght f n oes est n th rth rn p t f the North Am ri n e nt t d uthw d the m n s d t n the e tr l d so ther tate d M x c They a comm ly called wb d S P SERIFORMES

[J D B]

Junction diode

A sem du t ectify g dev e wh ch es th n bet e tw r g f pp it c nd n ty type t p odu e th rect fi t The de es a u ed i mp r s ad d t le bru files g n t r b tt ry h ge d le t o- hem al p oces es q g h gh d c e t nd lo h g The l e p w it e all lled sem d t d odes d the h ghe p e n t ll lled m d t r e tifier F d se n of d t ty t pe rr a d mp ties SE ICO D CTO

J t dod l fied by th m thod of p p at of th j t d by th m d t m te al A p rt I l t f g m um typ s l d g ld b d d ll y f d j ct n d gr jun t n S l typ al m m w e bo ded t l m n m ll y j t g w j t n, and d ff d j t In g m m t g ld bo ded t pes d f l w p w nd d m ll y types ed f h gh p we p l t Th f w g rm m g j ti d ff sed j t n t pes I l t th d ffi cult f m t h g th th rm l p n of th l n l tt th m ll y h led t a w d se l d ff d g w g t h q Low po l n j t d odes m l m d l l m m ll y bo d La l tvp d l y f g y th all y l d ff f p t es t th l d l f m the g ph g g th j t n d ri y t l p p t

Fabrication methods G l l l ded germanium d d ar made l y prepar g mall wafer of typ g rmani m about 40 mil n a d and 15 m l tl k After etching each wafer i ld red t m t l pedestal A mall g ld gallium all y wire w lded t a ec d p l tal Tl e free end of tl e g ld w r i the pl c l gai t tl urfa e f tl germani m waf r nd l nded (w lded) w th a p l e f c rre t D iri g tl w ld ng perati n me germani im i d l d l y th g ld and upon c ling reer stallize n tl f e f the i nd l d germanium Thi recry t ll ed regi n (F g 1) i *p* type beca it c t in m f th galli m mp rity f tl e g ld w r The juncti n r barrier f th devi i tl e bo da y l tween tl e recry tall zed *p*-typ r gi n d the undi l ed typ y tal

F ed l minum w r lic n d odes are f lri ted i a m and witl a re ult y imilar t g ld l nded germ ni m di d Tl e n s gnif ant differe i that tl bo ding p ati i carri d t l y l eat g tl e entir a eml ly rath r tha by lectri l pul ing

The higl p wer g ma m un t l ave all y ju t wh h i t f a l dary between a recry tall ed ll y *p* type r gi n d tl *n* typ mat r l f th g nal ry tal ju t in the g ld bo ded u t The d ffe en her i th t th all y u ually i di m inst d of g ld galli m a d the a e f the rec yst ll ed r gi is of the o d r of l m rathe th 10 cm Th fu n p oces carr ed t n f irn e d the y t l i m ted aft ward

The h gher p wer s l con unit ar m de by f t n f ery thi ti al m n m all y on on ur f ce f a il n w fer d lat r m t ti g w th ti ld Th j t n i tl typ cal ll y j n ti n lth gh the rec y tall ed eg n i e t mely th n A ec d m thod f m ki g h gh p we l n t t d ff e uit bl *p* type mpur ty apor t th rf e f a w fer f t p s l c n The mp ty apo i ually swept th w fer by a t d l fl w g tr g s After the mp ity h p t t d th w fer t a ffi t d pth to pr d a good p j ct n th w f i r mo ed

p-reg t
ll y g
p- i ct
ry ll d
sem d ct
p
m d ct w f
m t g pl t
g ct
sold

Fg 1 S t f b d d f

Other relatively rare forms of arthropathy are occasionally encountered See GONORRHEA HYPFR SENSITIVITY PNEUMOCOCCUS RHEUMATIC FEVER STREPTOCOCCUS SYPHILIS TUBERCULOSIS URIC ACID [F C S T]

Joint (mechanical)

The surface at which two or more mechanical or *structural components* are united Whenever parts of a machine or structure are brought together and *fastened into position a joint is formed (see* STRUCTURAL CONNECTIONS) Mechanical joints can be fabricated by a great variety of methods but all can be cla sified into two general types temporary (screw snap or clamp for example) and perma nent (brazed welded or riveted for example) The list that follows is not exhaustive but does include many of the more common methods of forming joints

1 Screw threads Bolt and nut machine screw and nut machine crew into tapped hole threaded parts (rod pipe) self tapping screw lockscrew studs with nuts threaded inserts coiled wire in erts drive crews *See* BOLT BOLTED JOINT NUT SCREW SCREW FASTENER WASHER

2 *Rivets Solid hollow explosive* and other blind side types *See* RIVET RIVETED JOINT

3 Welding *See* WELDED JOINT WELDING AND CUTTING OF METALS

4 Soldering *See* SOLDERING

5 Brazing *Se* BRAZING

6 Adhesive *See* ADHESIVE ASPHALT AND AS PHALTITE EPOXY RESIN GLUE MUCILAGE

7 Friction held Nails dowels pins clamps clips keys shrink and pre s fits

8 Interlocking Twisted tabs snap ring twisted wire crimp

9 Other Peening staking wiring stapling re taining rings magnetic Al o pipe joints are made with screw threads couplings caulking and by *welding or brazing* masonry joints are made with cement mortar [W H C]

Joule

A unit *of energy or work in the meter kilogram* ec ond (mks) system of units being equal to the work done by a force of magnitude 1 newton when the point at which the force is applied is displaced 1 meter in the dir ction *of the force Joule is a sh rt* name for newton meter of energy or work and hence is equivalent to 10 ergs and also to 1 watt sec The pre ent accepted relation between the 15 calorie and the joule is 1 cal_{15} = *4 1855 ± 0 0004* joules The term joule should never be u ed as a synonym for newton meter of torque" *See* WORK *see also* UNITS SYSTEMS OF [D F R]

Joule s law

A quantitati e relation hip betwe n th q antity of *heat* produced in a conductor and an el ctric cur rent flowing through it As *experimentally det r* mined and announced by J P Joule the law tate that when a current of voltaic electricity i propa gated along a metallic conductor the heat evolved in a given time is proportional to the resi tance of the conductor multiplied by the quare of the elec tric intensity Today the law would be tated as $H = RI$ where H is rate of evolution of heat in watts the unit of heat being the joule R is re i t ance in ohms and I is current in amperes This statement is more general than the one ometimes given that specifies that R be independent of I Al o it is now known that the application of the law is not *limited to metallic conductors*

Although Joule s discovery of the law wa based on experimental work it can be deduced rather eas ily for the special ca e of teady conditions of cur rent and temperature As a current flows through a conductor one would expect the observed heat out put to be accompanied by a loss in potential energy of the moving charges that con titute the current This loss would re ult in a de ending potential gradient along the conductor in the direction of the current flow as usually defined If E is the total *potential drop this los by definition* is equal to E in joules for every coulomb of charge that trav erses the conductor The lo s conceivably might ap pear as heat as a change in the internal energy f the conductor as work done on the environment or as some combination of the e The econd is ruled out however because the temperature is con tant and no physical or chemical change in a conductor as a result of current flow has ever been detected The third is ruled out by hypothe i leaving only the generation of heat Therefore $H = EI$ in joules per second or watts By definition $R = E/I$ a rati which has positive varying value Elimination of E between the e two equati ns gives

$$H = RI \quad (1)$$

which is Joule s law as stated above If I change to a new steady value I R to R and H to H then $H = RI$ as before The simple t ca e occurs where R is independent f I (*se* OHM LAW) If the current is varying the re ulting variati n in temperature and internal energy und ubtedly exi t and strictly peaking hould be all wed f r in th theory Yet in all but the m t ex eptional case any correction would be negligible

Thi ph nomenon i irrever il le in the en that *a reversal of the current will not reverse the* out flow of heat a feature of param unt imp rtance in many pr blem in phy ic and engine ring Thu the heat ev lved by an alternating current i f d *by taking the time averag* [illegible] Incidentally the chang in internal energy if th were included in the theory w ld average o t Hence th quation c ntinues to ha e a imilar form $\overline{H} = R\overline{I}$ f r alternating current appl a tion S e HEATING ELECTRIC [L C H]

Juglandales

An order f the plant [illegible] Dic tyl d nea c n si ting of one family (Juglan lacea) wit [illegible] in luding 60 p cie ccurri g prin ipally in th

ar cre ted by th captu e f lectrons by acceptor mp ty at ms wh ch rema n as fixed n g ti ely charged ent r In both a s the space h rge of th n ed imp ty e te ne tralized by the p ha ge of the maj r ty carrie

At a p- j nct the ba rier that keeps m jo ty m rs way con t of a dipol l yer f ha ged imp rity ce t rs p it e n the type id and g t o the p-typ id Wh n a r e e bia i ppl ed th b rie h ght increa and req ire m e harg in the d p le laye to produ e the r qui ed tep ltage In order t achie e thi th l er mu t w d n in e the i n ed impu t a e in fixed p tio in the ry t l A the layer widens, th cap ta c of the ju ti n d r a es in e th plates of the capac tor are farthe apart The ef e p n ju t on cts a a a able capac tan e s w ll ar able res ta c S e VARACTOR

Junct on d ode characteristics Figure 2 hows t p l rect fi t o sw t h g d ap cit c cha t ri t f a junct n d de From the recti fi ati ha t i t (Fig 2a) it can be en th t l its sh w much l we rev r e leak ge rre ts nd high ltage bre kd wns G ma m n t how l f rw rd b as ltage dr p t a g e rrent den ty S li n u t an be oper ted p to 200 C h le germ nium unit mu t be ope ted b l w 100 C

F swit h n p po t n n and t rn-off time a e m t p rt nt (e Fig b) The t rn t m f d od g rned by t j nct n capa tan d ll qu t f t Th t rn-off t me u ually the mu l h a te r i g v rned by th t me r qu ed t r mo e ll f the ess m n rity ar n rs j cted t b th th n d p-regi du t g th t m th d od w the f rward b st t Th t all d th mi ity rr er sto g effe t, nd t f th der f f w m o eco d f good w t h d od s S l c d odes a lly som wh t s p r t g rmani m n t th re- pect. F furth d s of th p p rties f p ju cti n e JUNCTION TRA SISTOR TRAN SI O S af POI T CO TACT DIODE [L P HL]

Junction transistor

A t a t r wh h the m tte d olle to b n rs e f rmed betw n sem nd to g s f oppo it duct v ty typ Thi typ of t n st r by f r th m t w d ly s d Ju t n tr sto s r ge in pow r at g f m f w m lliw tt (mw) t bo t 30 watt i c toff f qu cy f m 0.5–700 m g y l s (M) nd i g n f m 10–50 dec b ls (db) G rm n m i th m t wid ly ed emi d t mat i l alth ugh l s d for high ltag o high t mp at e appl t o In g n l j t t t appli ble t any p obl m n t r qu g p t n bo 200 C, 300 volts, o 00 Mc N t ll th se l mit n be a h ed in o devi of ou

J t t tor e la ified by the mbe nd rder of the r gi ns f d ff r t co d ct vity type by the meil od f fab r cating the tructure and s metimes by th princi le of op rat n

Alloy junction transistors Al-o calle l fu ed juncti n t an i tor thes are mad in th p-n-p and p n f rm The m tt r and c ll t r reg ns a e formed by recry tall zati f s mi ndu t r material fr m an all y of em co d t r m terial di l ed n me su tal le met l mixt r F r the germanium p- p all y juncti n tran t r the met l is u ually indium with a mall per entage f gall im F r th ge manium n p-n all y j nct n t an i t r th m tal may be m xture ch a l ad with antim y r b m th with r e i The maj r m tal f ch of the all y (d um l ad r b muth) erv a the s l ent f r g mani m The mi or lement serves a a ur e of the imp r ty n eded t render the ecrystall zed germanium op- po te i e nd ti ty type to the rig nal wafer The p n p ll y unit is th m r comm n type F r a gen ral descr pt n and def tion f th term ed h re e TRA SISTOR

F gure l c mp res seve al transi t r profiles which how h w the mpurity c nt nt ar es thr gh the stru t e In the e pr file C i the c n e tra tion f the p-type impurity a d C is the c n n tration of th n type imp rity The net mpurity cont t d term es the c ndu ti ity type and mag nitud (s SE ICONDUCTOR) The profile f the alloy t i t r sh ws th t th r i an ab upt ch ge f impu ty c trat n at the mitter d collector j ncti n and th t the condu t t of the emitte and llecto reg n i theref re high c mpa ed t that of the b e reg o Su h truc tu sh w g od mitte j t on efficiency but only mode te c lle t r ltag t g a d el ti ly high llect r p tan e

Grown junction transistors Th ar mad i the p- p and n p n f rms a w ll a n m re om pl cated f rm Th are e eral ariati n f the grown ju ct n t h j The s mplest o sts of c es v ly dding d ff t typ f mpurities t th m lt f m wh ch the m nductor cry t l is being gr wn A s m nd t crystal is u ually gr wn by d pp g the nd f a seed ry tal i to molte em co d ct d by r gi g the therm l g di ts that n w m condu to s lid fies on the e d f th ed s t lowl w thdrawn Th l d liq d nt f o ghl pla e pe pe dic la t th a s f w thd aw l A p- p str tur n be g wn by tart g w th a p type melt by add ng at ne po t i th crystal gr wth en gh type mp rity to g light e o th p type mp ty gi ally pr nt nd aft g wth h t ued f r a f w m r s by add g a e c s f p-typ mp ty to the melt Th l t g wn eg n w ll be th m tt r r g on a d the g l p-typ ry tal w ll be th c llect r gi n Th impu ty pr fil of s ch tr t re is h wn n Fig 1b Th h gh-c nd t v ty m tt r g n g e a good nje tion ffic e y a d th j n t n b tw e the b a d colle t r gi s i g d al e gh that th unit will how r l t ely l w

from the diffusion furnace and one surface is lapped and etched to remove the p type layer and expose the n type material for the n region contact

Junction rectification Rectification occurs in a semiconductor wherever there is a relatively abrupt change of conductivity type In any semiconductor *the product of the concentrations of the* majority and minority current carriers is a temperature dependent equilibrium constant The conductivity is proportional to the majority carrier concentration and inversely proportional to the minority carrier concentration When a p n junction is reverse biased (p region negative with respect to n region) the majority carriers are blocked completely by the barrier and only the minority carriers can flow under the barrier This minority carrier current is the sum of the individual currents from the n and p regions and each component is inversely proportional to the conductivity of its region In germanium of about 10 ohm cm resistivity a p n junction reverse leakage current is about 10^{-3} amp/cm² In silicon of the same resistivity it is about 10^{-7} amp/cm² because of the much lower equilibrium constant of silicon.

When a p n junction is forward biased (p region positive with respect to the n region) the majority hole and electron distributions can flow into the opposite region since the barrier is markedly lowered *Since electrons flowing into a p region or holes* flowing into an n region represent a great increase in minority carrier concentration the thermodynamic equilibrium of the holes and electrons is disturbed and the product of their concentrations increases as the junction is approached The resistivity of both the n and p type regions is considerably lowered by these excess minority carriers and the forward current is greater than the current through a geometrically equivalent bar of material containing no p n junction

The electrons in an n type semiconductor are given up to the conduction process by donor impurity atoms which remain as fixed positively charged centers Similarly the holes of a p region

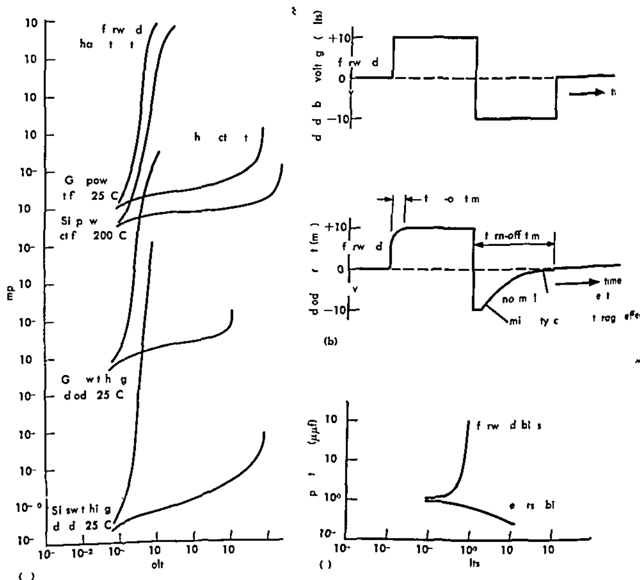


Fig 2 Junction diode characteristics (a) Diode rectification characteristic (b) Diode switching characteristic (c) Silicon switching diode capacitance

c ated by th c ptu e f electro by a cept r impurity atom whi h remain a fi ed n gat ely harged ent In both c es the pa e cha ge f th i ed impu ty centers is itr liz d by the pa charge f the maj r ty c rr rs

At a p n j t n the bar er that ke ps maj r ty carr rs away co ts of dip le lay r f charged imp ty te p t th typ ide nd g t on th p-type side When reve e b as ppl d the barr r he ght i c a es and qu re e ha ge n the d p le l y r t p du the re qu ed t p i ltage In rde t achie e th the l er m t wide since th zed impurit es are i fix d po it the cry tal As the lay r de s, the c pa ita of the ju ti n d re s ince the pl t f the c pacit r are farther apa t The ef e a p j t on acts as a a able ap i u ea ell s a ari bl esi t nce S e VARACTOR

Junction diode characteristics F gure 2 h ws t p al ect fi ation, swit hi g nd ap ta har te i t cs of a juncti n d de From the r t fi atio ch teri t c (Fig 2a) it can b see th t s l n un t h w m ch l w r rev r e l akage currents a d h gh lt ge b e kd wn Germ n m ts h w l we f rward bia oltag drops t gi n urr t de ty S l c n t ca be op ated p t 200 C l le g rm ni m n ts m t be p ated bel w 100 C

F t hi g p po es turn-on nd t rn-off times are m t imp rta t (ee F g 2b) The t rn-on t me f d ode g rn d ly its ju ct capacit e a d s lly qu t f t The tu n-off t m su lly th rit e l h t t c is g erned by the t m r qu ed t r mo e ll f the e cess m ty car ners injected to both the a d p-regi dur i g th t me the d d w s in th forward b tate Th e lled th mi o ty rrie t age ffect d t i f the der f a few m ros co d f good swit h g d de S l n d odes a u ally somewh t uppe t germ m u its in th pect. F f rthe d to f th p pert e of p-n j n t JUNCTION TRANSISTOR TRAN SI TOR s al POINT CONTACT DIODE [L.P HU]

Junction transistor

A tr t r h h th em tter a d ll t b re r f rm d betw mi nd cto g ons of ppos t co d ti ity type Th s typ f t an tor by f the m t w dely u ed Jun t t n t s a g po t g f m few m lliwatts (mw) t abo t 30 w tt t ff f q y f om 0 5–700 m g y l s (M) d g n f m 10–50 dec bels (db) G rm n m i the m t w dely u ed m c d t m t al altho gh s l n i ed for h gh lt g r h gh temp at e ppl c tio In t l ju cti t an to e ppl able t a y lectr mpl fi ati d t ct wit h g probl m not equ i g p r t n bo 200 C, 300 volts, r 00 Mc. Not all the l m t c n b ach d in e d i f cour

J n ti n tr to l fied by th numbe a d o der f the r g n f d ffe e t d t ity type by the m thod of fabricating the stru ture and met me l y tl e principle of p rat n

Alloy junction transistors Also call l fu d junction tr n tor these re made i tl e p n p and p n f rm The emitter a d llect r r gi ns a e f rmed l y recry tall zat f mi nd t r mate al from an all y of emic duct r mat rial di lved in s me su tal l metal mixt re F r the g rmanium p-n p all y ju ti n tran i t r the met l i u ually indium with a small perc ntage of gall im F th g rman m p n ll y j i ti n t an t r the m tal may l a m xtu e s h a lead w th t m ny r l m th w th ar n c Tl e m jor m tal f each f the all y (ind m le d or bismuth) erv a the sol t f g rmanium The m r el ment serves as a s rce f the impurity needed to r der the r ry tallized g rman m oppo te in nd ti ity typ t th rig l wafer The p p all y unit the more c mmon type For a gen l des r pt n and definit n f the term u ed h re se TRANSISTOR

F gure l c mpares everal t n i t r p files which show h w the imp rity c t t varies th gh the truct e In these pr f les C is the o c tra t on of the p-type imp rity and C the concen t t on of the n typ impurity The net impurity conte t determi es the ducti ity type a d m g nitud (s SE ICONDUCTOR) The pr f le f the all y tra tor show that there is n l pt ch g of impu ty concent at n t the em tter and collect j ncti ns d that the cond ti ity of th mitter a d collect g i th f high mpared t that f the b r g n S ich a tru tu how good m tt r inject effi y but nly mod rate c ll t lt g rat g and rel ti ely h gh lle t r cap cit nc

Grown junction transistors Th re mad i the p n p a d n p f rm w ll a m m e c m pl ated f rm Th e e er l var at s f the gr wn j nct on tech qu The s mplest c i t of s es i ely add ng d fferent types f imp ities t th melt fr m wl ch the s m c duct crystal i b ng grown A semicond t r cry tal is ally g own by d pp ng tl e e d f a seed cry tal int m lt n m c d ct r a d b v g g th therm l g ad nt th t new emi d t l d f es on th d f the ed a it i l wl withd wn Th l d l q d t f ce i r ghly pl n perp di lar t th a of w thdraw l A p n p t uct e c n be grown by t t g with p type m lt by dd g t ne po nt n the cryst l growth n ugh typ mp ity t gi e l gh e c s e the p typ mp r ty orig n lly p es nt and ft r g wth ha t nued f f w m c n by add g of p-typ mp ty to th m lt The l t gr wn g n w ll b th mitter g n nd th g nal p-typ cryst l will be the ll to r gi Th imp r ty p file f s ch str ct re s hown n F g 1b Th h gh c duct v ty m tter reg n g g d njecti n effi e a d the ju ct n be tw the ba a d coll t eg n i grad l gh o th t the t w ll h w a lati ely low c ll ct cap ta a d high b ekd

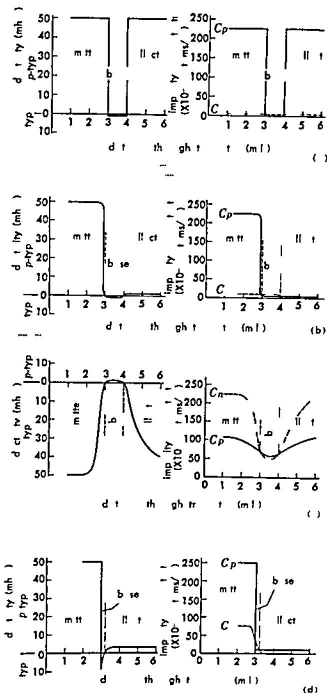


Fig 1 Co d ct ty and impur ty p fl s of typ cal ju ct o tra s tors (a) p p alloy j nct on tran stor (b) p- p g own j ct on t a sto (c) p-n te-g own ju ct o trans st r (d) p n p po t-alloy d ffused junct on trans stor

age The one disadvantage of this method is that both the collector and base regions show relatively high series resistances

Rate grown and remelt junction transistors These are a subtle variation of the grown junction technique If a melt contains more than one im purity the proportion of each impurity picked up by an ad ancing solid interface will vary with the speed of advance With the proper choice of n and p type impurities one can grow an n p n tran si tor structure in germanium for example by radically slowing down the pulling (withdrawal) rate for a hort time Sometimes the pulling is actually reversed (hence the terms remelt or melt back) The impurity profile of such a structure is shown in Fig 1c Grown junction techniques are more widely used in fabricating silicon tran i tors than germanium transistors

Diffused base drift transistor In this tran i tor the minority carrier transport across the ba e region is achieved by the effect of a strong electric field built into the transistor structure by a fabrica tion technique called diffused ba e In the typical alloy junction transistor (uniform ba e conducti ity) the minority carrier transport acro s the base is achieved by a relatively slow diffu ion process In the drift transi tor the ba e region shows a high conductivity gradient decrea ing from the emitter to the collector (ee Fig 1d) This conductivity gradient means that the majority carrier concentration is much greater near the emitter than near the collector In order to cancel the natural diffusion of majority carriers from the high to the low concentration region an electric field must exist of such a polarity as to tend to drive majority carriers back toward the emitter This polarity of field then tends to dri e minorit carriers from the emitter to the collector when normal bias is applied to the device exce s injected minority carriers will be accelerated acro s the base by this field

The method of producing the conductivity gradi ent in the base is usually some sort of olid state impurity diffusion technique One of the mo t u e ful is the formation of an alloy emitter region which contains both n and p type impurities For germa nium the p type impurity is caused to be much in excess and gives a p type recrystallized emitter re gion The n type impurity however ha a much faster rate of diffusion and soon penetrates the original wafer beyond the recrystallization bound ary If the original wafer is p type with a relati ely low conducti ity the n type impurity diffu ing out of the recrystallized emitter region is in exce near the emitter creating an n type base region with the required conductivity gradient Such a technique as this is called by a variety of names diffused base post alloy diffusion pushed out ba e or simply diffu ed

Drift transistors The e show the highe t fre quency cutoff and the fastest switching times of any of the junction transist rs Typically they ha e good collector voltage ratings and low collect r capacitance l ecause of the graded nature of the colle tor juncti n The emitters h wever can with stand only 4–5 olts of reverse bias and show a high capacitance which often limit the frequency re ponse of the de ice

P N I P junction transistors The e tran i tors are intended for high freq iency operati n They minimize ba e transit time by making the l a e un usually thin and they reduce c llect r capacitan e by making the olle t r junction unusually thick This is accompli hed l y in erting an intrin ic re gion (i region) betwe n the l a e and collector regions An i region i ne in which the net number

of imp ties (minu p) ery low and hence the d ti ity ry low The frequency range f ch tr t r i n t h gh that f d ft tran t s, b t t h gher than that of alloy tran t rs. Both p and p p types exi t

Tetrode transistor Th t t h s tw hmi t cts on opp site sides f the base r g n If the mitter is b ed w th rel t n t one of the e co t ts a d th the base c t ct g dc b f the m p l ty as the emitter b t of gre t r m gn t de t is p ble to limit the f rw d bia ed ea f the em tter junctio t a m ll g o ear th first b ntact Since min ty c ers g es e t ally straight a th base t the llect th w ll al l m t the l m f the b i l ed t a reg n close t the fi st b se t ct. Th l w rs the ba e e resista e and th ref e ct a. the freq cy resp f th dev ce Th p p rt n of jected iers I t to th base hil in tr n t t th llector h w ev is incr d Th l wer th curr t gai of the dev e

Power transistors The e e u d in th tp t tag f a lect o c cu t both s w tches d mpl fie (CONTROLLED RECTIFIER) Depending o the l d, high lt g r ting a h gh rre t at g h h pow rat g m y be required W th a y f the he t d pat n w th n th d e is a ri l mit t F g e 2 h ws th ri t on f gr ded em tte -curr t ga with emitt c rre t f typ cal p-n p j tio pow r tran ist F m th urve t an b se th t a high rre t t g s bt ed t rio los f gain Act lly the 'll t at d d p n g i i a functi n f c rr t de ty so that tech l gi l imp m nts ll wi g l g em tter nd llect c nta ts w ll g e tly impr e the h gh urr t p rf rm Usu lly l ge- ea em tt r and llect r t ts atte d d by ge met cal compl ty poo qual ty j n t s r both S l

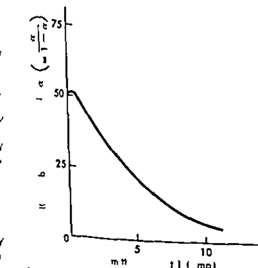


Fig 2 V w h m tt t f mm m rr t g (ll y p w t t

c n offe great p om e t the power tran i t r field b cau e it is c pabl of higher temperature operation a d co der bly h gher ltage rating These ad a tag a e ff et by it mor d ffi ult technology a d by the r lat ly large lt ge dr p of silicon t a t at high saturation cur rent

Summary The followi g ompari n may be made f the different ju t n tran i t r types Germanium all y t an i tor are u ed in the a d o-fr q cy field a d t a lesser exte t in the power field a d in the mod ate-speed switching field Their c t ff f equenc ra ges from 50 kc for me of the p wer types t 0 M f som f the sw t h ing types Power r t ng ra ge from 100 mw t 30 watts a d oltage ratings re 0–150 v lt Silico diff ised j ction grow junct n types h w appr bly h gher volt ge a d power rating (300 lt and 50 watt) l ut h e low frequen y a d curre t rati g In the h gh f q ie y fi ld th drift t ansi t is m t u ed G rma um drift tr n i tor r nge p t 400 M in freque cy cutoff and h e abo t 50 mw p w r rat g Silic n d ift tra tor ang p to bout 00 Mc i freque cy utoff I gen l m t sil on t n tor will operate up t 200 C, wh le g rma um tr n i tor m t be k pt b l w 100 C [L.P.H.U.]

Bibl g aphy L. P H ter *Ha db k of Sem c d t Elect cs* 1956

Jupiter

The la ge t plan t i the l r system a d the fifth the rd of d sta ce to the Sun It i i i ble t th naked ye x pt fo sh rt per od whe t i nea its nj ct n w th the S U ally t i th ec d bright t pla et in the ky O ly M s at it ma m m lum no ity a d V n pp b ighter Jup ter s b ight tha S i the br ghtest fi ed st

Planet and its orbit The m i orb tal leme ts ar a mim j a r mean di t nce t Sun f 485 × 10 mi n ec nt ic ty of 0 048 causi g the d t ce to th S n t vary abo t 47 × 10 mi betw pe h l n d phel n d real rev l ti p i d f 11 86 y r m rbit l l city of 8 2 m / e a d li t of b tal pl e t l pt c f l 3 *S* PLANET

Th appa ent q t i l d meter of it d k a e f m b t 47 t me n opp t (50' t p hel c pp t 44 at ph l pp iti n) t 32' t o j t The p l flt te i g d e to t p d ot t i n ide abl nd i ly det t d by u l n pect o th llipt ty (−)/ = 0 065 whe e i the eq ato i l d s d is th p l r rad Th eq tori l di m t b t 88 00 m a d th pola d mete i 82 800 mi The l m is b t 1317 (Ea th = 1) with n e t ty f few p c t The m i ab t 318 4 (E rth = 1) a d s ac u t ly d te m d f m the m t f th f r m j t l l t The m de ty 1 34 g/ m a l w l e h t ti of th f m j pl ts th r e p d g alu f the mean l r ti f gr ty

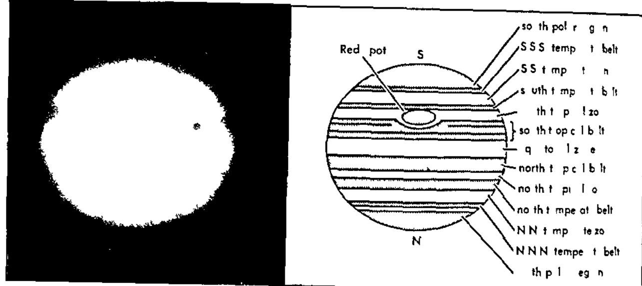


Fig 1 Telescop c appearance of Jup ter and nomenclature of p cipal bands

at the visible surface is about 26 m/sec² however because of the rapid rotation the centrifugal force at the equator amounts to 2 25 m/sec reducing the effective acceleration of gravity to about 24 m/sec²

Phases As an exterior planet Jupiter shows only gibbous phases however because of the large size of the orbit compared to that of Earth the maximum phase angle is only 12 at quadratures and the phase effect shows up only as a slightly increased darkening of the edge at the terminator The apparent visual magnitude at mean opposition is −2 4 and the corresponding value of the reflectivity (geometrical albedo) is about 0 4 the physical albedo is 0 45 with some uncertainty due to the small range of phase angle observable The high value of the albedo characteristic of the four major planets indicates the presence of a dense cloud laden atmosphere *See* ALBEDO

Telescopic appearance Through an optical telescope Jupiter appears as an elliptical d k strongly darkened near the limb and cro ed by a series of bands parallel to the equator (Fig 1) Even fairly small tele copes show a great deal of complex structure in the bands and disclo e the rapid movement of rotation of the planet The period of rotation determined from long eries of observations of the bands at the central meridian is very short about 9h55m the shortest of the main planets The details observed however do not correspond to the solid body of the planet but to clouds in its atmosphere and the rotation period varies markedly with latitude The nomenclature and mean rotation periods of the main belts of clouds are given in Table 1 The rotation period of any given zone is not exactly constant but uf fers continual fluctuations about a mean value O

Table 1 Mean latitudes and rotation periods of J piter s ba ds (after B M Peek)

Band	Reg on	Latitude	Period 9h+	Rema k
North pol r r g on		> +48	55m4	
N N N temper ıte belt	Center	+43	55m20	Temporary
N N tempcr te l elt	Center	+38	55m4 s	Temporary
	So th edge	+35	53m55s	
Nortł tem erate belt	North edge	+31	56m0 s	
	Center	+27	53m1 s	
	South edge	+ 3	49m0 s	
Nortł t opical zone	Center	+18	55 n 9	
Nortl t op l belt	C nt r	+13	4m09s	Tempo ary
	South edge	+6	0 4	
Equator al zone	Middle	0	50m 4s	
South tropical l elt	Nortl lge	−6	50 n (	
	Cel t r	−10	51 n 1s	
	Soutl edg	−19	5 m39	
South tropic ıl zone	C nt r	−3	55 n36	
Great Red Spot	Cent r	−	ı 38s	
Soutł temperate belt	No tl dge	−	3m0	Tempo n y
	Cei ter	− 9	n 0	
	South edg	−31	m0	
S S temperate zone	Center	−38	5 m0 s	
S S S temperate zone	Cent r	−4	5 m30s	Temp ry
South polar reg on		< −4	30s	

asion l sh rt li ed atmo phe ic phenomen may depart more strongly from the m a r tatio period of the zone i h h they appear and thus drift p dl w th respect to othe det ils i the zone The ot u n axi is i l ned only 3 to the p rpen di lar to the rbital pl e so that seaso al ef fect a p act ally neglig ble

R d Spot Ap rt fr m the c n ta tly cha ging deta ls f the belts me p rmanent r emiperma ent ma k gs h e b en ob erved t la t fo de des o even ce tur es w th s me fl ctuatio in i b l ty Th most con picuo s d pe manent marking is th g eat Red Spot intermittently recorded sin e th middle of the e tee th cent ry and observed cont uo ly s e 18/8 whe its trik ng redd h c lor ttracted g neral att nti n It co p c s nd st ongly colored aga n i 18 9-188 1893–1894 1903 1907 1911 1914 1919–19?0 1926–1927 a d espec lly i 1936–1937 t oth times it h s bee faint and only slightly col ed a d oc on lly nly its tl ne or th t of the bright bay r hollow of the th temp r t e zone wh ch urr ds t h s r ma ned vi ble (see Fig 2)

Th m ot t n per od of the Red Spot be tween 1831 d 1955 was 9h55m37.5 w th a r nge of natu n of bout ±6 sec. The mean d m io f the Red Spot are about 30 000 m les n lo gi tude nd 10 000 m le in lat tude

Othe ma ki gs An th emark bl miper mane t m rki g the South Tr pi al D tu ban e as interm tte tly b erved o Jup t r between 1901 nd 1935 nd p s bly al o 1940 Th s mark ing e rc l ted in th s me one s the Red Sp t, b t with sh rter m n rotation period bo t 9h55m16s a d p riod c lly ame int nj ct n with t. A large numbe f temp ary feat es of h rter d r ti n ha e be n obs rv d but th ir mech ni ms of f rm ti and l w of m ti ns re t unde stood

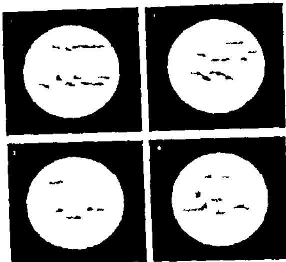
Th loc t on of p ts the i ble urf ce of J p ter re r rded in tw l ngitude ystem O S st m I b ed on a rotat o p riod f 9h50m30 003 s d f r ep t n th eq tori l zo e the her Sy tem II b ed a r t t p od f 9h5 m40 632s u ed fo p t outs d th Th pe iod f tatio of y g spot b g iabl d t e ily q al t th mea p d f e th l g tude sy tem there is a g ner l d ft h h afte a ffi tly l ng t m c ex ed one m mpl te turns that i a x eed 360 Th d ft i l g tud of th Red Sp t with pe t t Sy t m II b tw the ye 1831 a d 1955 h n F g 3

Atmosphere Th pt c l p t m f J p t r h ct ed by tr g b orpt n b ds f meth a CH d mm NH the t mat d qu tit es f the g p t th tm phe bov th l d lay b g f th de of 150 m in thickness at t d rd t mp r t nd p es (STP) d 7 m STP r p t ely Th r t l l t dic t that hyd g nd h l m m t lso be p es t d rect b rv t s of th ult tion f a star by Jup ter ha e co firmed th c n cl ion

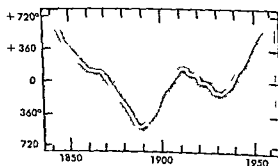
The radiom tri lly determ ned t mperature of the vi ble s rface of J pite about 130 K i in f irly good ag eement with the v lu theo et cally estim ted fr m the assumpti n that th v il le l ud l yer is ma ly i e cry t l of solid fied am m ni (about 160 K)

The lors of the cl uds of Jupiter ha e been att ib ted to the presence of v r u met ll c im p rit es such as d um r potassium n the atm sphere

Internal structure Various theoretical m dels of the internal struct e of Jupiter calculated after 1930 had s gge ted the following constit ti n a relat ely small i er core f rock and i on sur ounded by a thick ma tle of several arieties of w te i a d oth ice und ery high p essures and at very low temperature and abo e this an ex tensi e l q d and g seous atm sphere who e up permo t laye ly a e i ible Howe the di co ery i 1954 of the m s o by J p ter of tro g p l e f onth rmal r d o o se at wa elengths l e t 15 m led a tr ome to que t on uch m del d t c n de the p sible p ese ce of hot ene gy o rces u de ol d surface t a mode



Fg 2 V bl b l ty f the R d Sp t (1) 1929 (2) 1933 (3) 1936 (4) 1938



Fg 3 D ft l g t d of th R d Sp t b tw 1840 d 1955 (Aft B M P k)

ate depth below the optically impenetrable cloud cover The recurrence of radio emission in certain longitudes indicates the existence of sources of en ergy rotating with a constant period of 9h55m29 6s and suggests the presence under the clouds of a solid surface rotating with this period *See* RADIO ASTRONOMY

The existence of an inner solid body at a high temperature appears to be confirmed by measure ments of the thermal radio emission of Jupiter at wavelengths shorter than 10 cm which indicate ra diation temperatures of the order of 600 K Earlier theoretical models of the internal structure of Ju piter are in need of considerable revision as a re sult of these discoveries

Satellites Jupiter has 12 known satellites of which the first 4 I Io II Europa III Ganymede *IV Callisto discovered by Galileo in 1610* are by *far the most important The main elements of the* 12 satellites are given in Table 2

The four Galilean satellites are of fifth and sixth stellar magnitude and would be visible to the naked eye if they were not so close to the much brighter parent planet All the others are faint telescopic objects The fifth satellite discovered visually by E E Barnard in 1892 moves inside the orbit of Io the others move in much larger orbits outside that of Callisto and have l een discovered photo graphically since 1900

The mas es of the major satellites can be roughly estimated from their mutual perturbations in terms of the mass of the Moon as a unit the mass of III is about 2 of I about 1 of IV about ⅓ and of II about ⅔ The four Galilean satellites show measurable disks easily seen with telescopes of 6 to 8 in aperture larger telescopes show dis tinct markings on the disks (Fig 4) The apparent diameters are of the order of 1–2 and the corre sponding linear diameters are listed in Table 2 Ganymede and Callisto are larger than Mercury l ut smaller than Mars their densities about 2 5–3 g/cm^3 *are approximately the same as the density* of the Moon and of the Earth s cru t Observations of their surface marking and the regular aria tions of brightne s as they move along their orbits indicate that the four major satellites (and

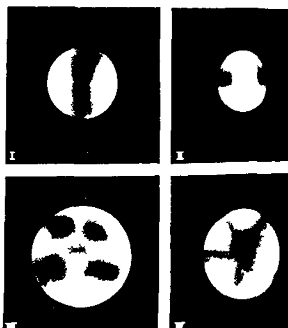


Fig 4 Telescop c aspects of the Gal le n satell t



Fig 5 S tell te phenomena

probably also V) always present the same face Jupiter much as the Moon does to the Earth th is their periods of rotation are equal to their p riods of revolution The albedoes for I II a III are relatively high however IV is very da and has an albedo maller than that of the Moon

The planes of the orbits of the major satellit are inclined less than 0 5 to the equatorial pla *of Jupiter o that with the occas* nal excepti of IV they are eclipsed in Jupiter shadow each revolution and al o project their shado s Jupiter and tran it in front of its di k near c njun ti n The eclip es transits and occultati n

Table 2 Satellites of Jupiter

Satell t	M n di tance fro n J ipiter 10 miles	Si l real pe od l iy	Diam t r i il	M g tu l t me n j po itio	All l (i i l)	M (Moo =
I Io	6	1 769	300	(i)	0 3	1 0
II Europa	417	3 5 1	19 0	5 (i)	0 3)	0 6
III Ganymede	666	155	3 00	1 ( )	0 0	1
IV Call to	1 1 0	16 (8)	3 00	6 3 ( )	0 03	1
V	113	0 498	1 0	13 0 (vi)		
VI	7 1 0	0 6	100	13 (i)		
VII	90	– 9 (	3	17 0 (p t)		
VIII	14 600	3)	3	1 0 (p t)		
IX	14 00	8	1	18 ((p t)		
X	300	(0	1	18 8 (p t)		
XI	14 000	00	19	18 4 (p t)		
XII	13 000	6–	14	18) (p t)		

J pter s tellites (F g 5) led t the d co ery of the fi te veloc ty of p pagatio of light by O Roemer in 1675 S e ECLIPSE ASTRONO IICAL OCCULTATIO TRANSIT (ASTRONO IY) The very small o ter t ll t s of J piter may be c pt d astero d the b t are bje t t l g perturba tion b th S and it is possible that at lea t the more di ta t es m y b l t by the pl et t some f t e tim

[G D V]

B bl g phy B M Peek *The Pla t Jupiter* 1958.

Jurassic

Th i m f rock d po ted d ring the middle p rt f the Mesozo c Era. The Jura y tem rm ll u de l n by the Tr a c d o erlai by th Cretaceo ystem It w named aft r the J M ta n S it l d a d i ts mai ly f ed me t ry ock V l nic ocks are rest ted t rt n regi p rt l rly the N rth Americ Co dll a Th d at n of the J c P r d b h d d bo t 127 000 000 ye s ag esti m ted t be abo t 25 000 000 y

PRE CAMBRIAN		PALEOZOIC							MESOZOIC			CENOZOIC	
						CARBON IFEROUS							
A EO OIC (EA ECAM AN)	OTE O O C (LATE P ECAM AN)	CAMBRIAN	ORDOVICIAN	SILURIAN	DEVONIAN	MI I ippi	P yl	PERMIAN	TRIASSIC	JURASSIC	CRETACEOUS	TERTIARY	QUATERNARY

Subdivision Th Ju c sy tem co st f the ma di ns th Low M ddl nd Uppe J Li s, D gg r and M lm Bla k B wn d Wh t J th term appl ed t these d n m c t i pa ti l ly Germ ny F r ubd i t t ge (hr t at gr ph u ts) and e (b t at g ph u t) a e b d m ly on th th e t E ope ta d rd ti n The H tta g S m ri Pl en bach a d T r n st ge f m the Lowe J a c th B joci n d B th n a f m th M ddl Ju d th Call i O f d K mm dg n P t l d an d P be k f rm th Upp J I some unt the C ll an l d d the M ddl J Up t th K mm dg an th tag m e in wo ld w de u e b t d t e- gi l d g i t n f th f u n the yo g J oth t g m ha e be tr d d f these b ds, f mpl V lgi n R a d th A t a d T th i n M d t r eg Th t ges gr p gs l e wh h b ed rta pec es f mm t (d Amm n d f Cephal pod) ha t t of t bed d i m ny se f w ld w de d t but S CE HALO DA F S ILS

The n rthwe t European standard section is now bd ded int 58 amm nite z ne Local faunal d ff e tati n ha e resulted in separat z ne e- quence f r e t egions and ome zo es may be ba ed on fo l ther than ammon t s f r e ample the pelecypod g *Buchia* (*Auc ll*) in the Up- pe Ju a ic S e PELECYPODA FOSSILS

Oth r ubdi i n of the syst m are formati ns mainly defined by l th l gy whi h f rm the l a i f geologic l mapping In North America f rma t n names e exten ely u ed In Gre t Brita n format name such as Lias I feri r O lite Cornbra h Oxf rd Clay a d ther a e in u e and a me of the e r ck units traceable t other count e th me n me ha e bee appl d The ge of f rmat n name for mappi g ha great ad a tage h we r w ld wide correl tio are b ed o tage and z e

Paleogeography Ma y autho ities deny the f r mer e i te e of l ge tine t a d la d bridges the region f pre ent-d y oce s with s me ex cept n I tead a rel ti e permane cy f o ean a d c t ent is n w wid ly cepted During the Jur ic the Pa fic the N rth Atla tic the Sc n d and the A ct cea s we e in xi tence The N rth Atl tic d Scand c were pr bably ep rated fr m on n ther by a l nd br dge ext nding f m Sc tla d t I ela d d Gre nla d A there e n kn wn mar e Jura ic deposit n either s d f the S th Atla ti th ex st nce of an Af r n B il n nt ent th t f rmed th western h lf f G dw n l nd m y still be co sidered a p bl Th ea t rn h lf of Go dwa la d w n the p e nt-d y I d n Oc n which w s pr l bly d y la d d i g the J ra i a d f rmed the Aus- t lo-I do-Madag sca c t e t r Lemu ia The west rn d ea tern pa ts of Go dwa al nd wer sep t d f m n a th r by a J a sic ea n the a t s de of Af ic Th m i e depo its of the Jur s o ea a e conce led bel w the floo of th p e t o ea All kn wn mari e Ju assic de p s t oc in p rt of the ti e ts wher they w e dep it d n comp rati ely h ll w w t The s h rdly gle ep i ic (h ll w nl d) se wh ch r ma d n n nd the sam reg o thr gh ut all f the t m ted 25 000 000 years of the J r s Per d The dur ti n of the J r i m r t a g es s s d p dent th ch r t f th p rt of the ont t whi h wa flood d St bl h l es h a tho the E pe p rt of Ru g lly ha e f ly thi d n om pl t of J r s c d me ts wh as l s st bl hel e h th n n rthw t E rop ha e der bly thi k d p it

G t th k es of s d me t we c umulat d th geo yn l al reg ns, a f ex mple th Ame C d ll r wh h f rm d p t f th m P fi m b le b lt. A the m b le b lt the T thy e t ded f m th Med t rr ne n t Pe the H m l y s a d I d s a S h ge sy cl were r pdly d e t n ly s k g t gh Th f th q ally f t r g rr und ng l d m d t q nt t e f ed ment ailabl

for filling them In spite of their rapid sinking the depths of these geosynclinal seas were not (with some exceptions) considerably greater than those of the more stable areas as the speed of sinking was compensated by rapid filling Typical shallow water deposits are common in such geosynclinal seas *See* GEOSYNCLINE

The Precambrian shields which form the oldest and most stable parts of the earth s crust were land areas subject to erosion during the Jurassic Period Thus in North America the Canadian Shield was land bordered by seas both to the north and west and the Scandinavian Shield was sur rounded by seas in Late Jurassic times (Fig 1) Smaller areas underlain by older rocks such as the Bohemian Mass the French Central Plateau the Belgian Ardennes and the German Hartz Moun tains were lands the coastlines of which are indi cated in many places by conglomerates and sand stones (Fig 2) *See* PRECAMBRIAN

The faunas of the Early Jurassic particularly the ammonites seem to have been universal and distinct faunal realms can scarcely be recognized for this time During the early part of the Middle Jurassic (middle Bajocian) a Pacific province seems to be indicated and somewhat later in the Jurassic (possibly Callovian) a boreal realm is de veloped in the Arctic and parts of Russia Its am monite faunas are clearly distinguished from those of the realm of the Tethys These faunistic differ ences do not necessarily indicate any differentia tion of climate which apparently was very uniform

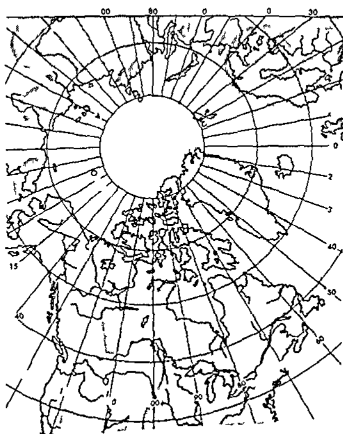


Fig 1 O fo d n pal ogeography of the Bore l reg on

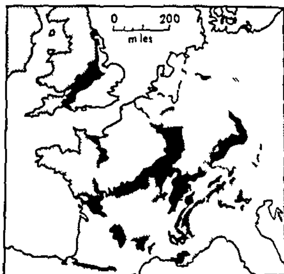


Fig 2 Distribution of Jurassic outcrops in west central Europe (From R C M ore Int oduct on to H s to ical Geology 2d ed McGraw H ll 1958)

as indicated by the fossil vegetation Jurassic gla ciations are unknown

Tectonic history The Jurassic Period was for most parts of the world a time of comparative tec tonic passivity diastrophism of a major order and connected with the intrusion of batholiths was re tricted to the North American Cordillera Moun tain building connected with volcanic activity took place in the Crimea and Caucasus and minor folding and faulting (the so called germano type folding) is known from northwestern Germany and other areas In the North American Cordillera two major episodes of diastrophism are recognized the Agassiz and the Nevadian phases The Agassiz phas took place at the boundary between the Mid dle and Late Jurassic the Nevadian orogeny at the end of the Jurassic Period While the Agassiz pha e seems to be restricted to parts of southern Briti h Columbia the Nevadian phase resulted in the up lift of great parts of the former Cordilleran geosyn cline This new land was consequently sul jected to erosion and the eroded material was deposited in the east where it contributed to the sediments of the Lower Cretaceous Intrusion of large batholiths in the North American Cordillera and widespread ol canic activity were not restricted to these two epi sodes of tectonic diastrophism but took place al o during part of the Early and particularl Middle Jurassic Germano type folding affected many parts of the world within belts of earlier folding which had not yet become entirely stable Orogenic move ments of this type occurred during the Late Trias sic and perhaps earliest Jurassic (early Cimmerian phase) The late Cimmerian pha e of many regions is ab ut equi alent to the Nevadian orogeny and I subdivided into the Deister phase l etween the Kimmeridgian and lower I ortlandian and the O terwald pha e between the lower and upper I ort landian *S e* BATHOLITH

Of utmost mporta c in the hi tory of the Juras si Period w re the ep r g n c r ovements Th y ere the ma n cau e of the tran gres ion and e gres s of the sea of the openi g and l ing f se way nd f the migr ti ns of faun s Th y also influ ced the r te and chara t r of the edi ment ton *Se* DIASTROPHIS t OROGENY TEC TO IC PATTERNS

Life of the Jurassic The Jura s flora is char act rized by fern which occur abundantly in c rtain r g ns and by num r s gymno perm Am g these the cycadeoids (Bennettital s) uch a *Taeniopt ris Nil sonia* a d *Pte ophyllum* ex tinct palml ke pla t relat d to the modern cycads we e d m a t Ginkg s wer w dely d tributed pines cedar nd th o ifer we abundant Th p e e of a g o p rm is nd cated by poll n grain *Cal a o* alg b ilt r fs n ome m ri e a. The mparati ely g e t uniformity f the J a i l nd plants doe not s g t th ex ten e of l m tic nes

R pt l e e epre nt d by a gre t numb r of d ff rent f rms. On th la d the din urs w re th d minating f rms, *represented by the* rders Sau t schi with h pbo es *omparable to tho e f* the rept'l nd the *Ornith* h a with mo birdl ke hipbo tri tu Am ng the *Saur* ch a both mall and g nt f rms we e p es nt *Comps gn thus* w abo t th e *of a ch cken* wh l th b ped l arn *Allo u us* *ttained gig ntic* *it R* t s u *us* an amphib s f u *footed* p la t g d n aur r a bed a l ngth f mo e than 60 he pl nt-eat g Orn th chia we e rep e t d ped l Orn thopoda a d th hea ily plated truped *St go a us* l the ea *Pl o a u* the k *Ichthyosa us* and c ocod le such as os *us* (up to 18 ft lo g) were loc lly bun n the ai the pte osa r we e r p e ent d by *odactylus* and the s

el tons of the fi t b d *A chae pte y* whi h had ptil an j ws and *te th and* trong h p b ea t gi dles *lik* the pt aurs w e fo d h Lat Ju a i l th gr ph t nes at Solen n B r a P acticall all gr up f m de n were p ese t n th J ic Of th g n ds more al f rm s h as *Gy d s L p dot s* and p d w e abu d t the t leo t we e *rep e* ted by *Lept l pts* a d th harks by *Hyb du* l 4 *o us* Of the amph l a f og a d t d pr sent Both n Engl nd nd N rth Ame i gme t mo tly *jaws* d t eth of sm ll ma mal g g t the Ma sup l a o ur The m t imp rta t m *ne n rt b ates of th* as r th amm nit s wh ch de elop d m ny f m lies nd ge era u k wn n th pre ed ng ic P riod Th r h rt ert cal a d w de h ntal g d th i ppe ran e lm t e erv es h e made th m the b t gu d f il of th i c. Oth J a c ph lopods a e n t l d id th ry b d nt b lemn ds. B th ga t opod id pel ypod e ll p nt d the l it ith mbe of ge a (u h a *Gryph Ino amus* nd *Trig*) of t l t l l imp rt c for age determinations and c rrelations The echi noid are abundant in certain region but the cri o ds are repre nted only by a few genera *such as Pentacrinus* The brachi pods are re tricted t a f w g oups S liceou ponges formed reefs locally and lime ecreting hydrozoan colonie were ab in dant in the Med terr nean reg Corals li d in certa n reg ons at arious times during the Juras sic Land invertebrates are repre ented by such in s cts a flie butterfl es and moth Am ng the rustacean o trac ds are known fr m both ma rine and f esh water beds and a e u ed for age de terminati ns *Se* I ALFOBOTANY PALEONTOLOGY

Economic products Iron ores of Jura ic origin *are pre ent in* Western Eur pe Tho e of Lorraine b lo g t the Middle Jurass c whereas tho e in Br tain ccur n both the Lower and Upper Juras sic C al i pre ent mainly n the Lower Jura c and th und lying beds of the Rhaetic in *many* part of the w rld i cl ding Arctic regio s Upper Juras c o l is kn wn fr m Scotland the Lol ten I la d and north a t Greenl nd Not all of th Jura ic o l occurrences are workable under p s ent co dit on Highly b tumi us rock and o l shal o cur in we tern E rope I ime a d cement re m de from alcareous beds n England and G ma y brick from the clays Lith graph c t ne comes fr m th Upper Ju a ic of Solen hofen Ba ari many good bu ld ng t nes f om ar us beds a q a r e d i il e J ra l *me* t n s f w tern Eu ope Pet l um i obtai ed f m vari s Jura c h rizo s in the United States Canad Mexico B zil Franc Germ ny Mo r c o a d Saud Arab a [H F]

B bl ography W J A kell *Jurassic Geology of the W ld* 1956 R W Imlay Paleoecology of J ras i s s in the w tern int r or of the Un ted States in H S Ladd (ed) *T e ise o Ma ine Ecology and Pal ecol gy* ol 2, Geol Soc Am Mem 67 1957

Jute

A n tur l fibe btained f om two A at c pecies *C rcho us cap ularis* and *C ol torius* f the pl nt der M l l (Fig 1) Th ar tall lender hall h bby nnual 8–12 ft tall (s AN UAL PLANTS) Wh h rv ted th tem re *retted* n ta k r pool to r t ut th oft r tissues Th t a d f jute fiber gunny are then loo e ed by b at ng the tem the face of the wat r The fib r a e not ery tr ng d d te iorate qui kly n the p nce f m tu e espe ally alt w ter D sp t the e weakn sses jut i mu h used It s xp ns a d a ily pun and converted t o e fabri It m de into gunny bu lap b g sa k f w ol p tato s cks e f r cotton bale tw n arpets rug c h ns urt ns, and a l n leum b e It i ls used n mak ng c ar e cheap fabr cs h a o lty dr good M i f th mme cial s pply comes f om pla ts g own n the G ge nd B ahmap t a alley i Ind S FIBE CRO S FIBE NATURAL M LVALES

[P D S]



Fig 1 Jute *Corchorus caps la s* (From P DeJa v ll *Atlas de Poche des Plantes Ut les d s Pays Chauds* L brarie des Sc ences Nat elles 1902)

Diseases of jute A number of diseases of jute cause losses in yield and reduce fiber quality Runner and specky fiber are primarily due to disease producing organisms

The fungus *Macrophomina phaseoli* is believed to cause the most serious di ease of the two species of jute It is seed borne and soil borne and pycnidiospores from susceptible plants besides jute also serve as sources of infection The stem leaves and roots of both young and older plants are subject to attack Stem infection usually takes place through a leaf petiole or at a node (Fig 2) Root rot is complicated in that severity is increased when *M phaseoli* is in combination with other fungi bacteria or nematodes such as *Fusarium solani Pseudomonas* sp and *Meloidogyne incognita* respecti ely



Fig 2 (a) D sease les ons on jute stems (b) Roots of jute plant affected by root knot nematodes Da k area on oots are early stages of root dec y

See BACTERIA FUNGI NEMATODA *see also* LEAF (BOTANY) ROOT (BOTANY) SEED (BOTANY) STEM (BOTANY)

In contrast to *M phaseoli Colletotrichum capsici* causes lesions on the stem internodes and may also attack seedlings and capsules of *C capsularis See* FRUIT (BOTANY) *Macrophoma corchori* and *Diplodia corchori* cause stem diseases Two species of bacteria *Xanthomonas makatae* and *X makatae* var *olitorii* attack the stem and lea es of both *C capsularis* and *C olitorius Pythium splendens* causes a root rot and subsequent wilt of *C capsularis* and indications are that other species of *Pythium* also are root pathogens of jute

Other fungi which attack jute are *Sclerotium rolfsii Curvularia subulata Cercospora corchori Rhizoctonia solani Helminthosporium* sp and *Alternaria* sp

Seed treatment with an organomercuric material such as Ceresan Granosan or Agrosan GN should be practiced for control of seed borne pathogen and seedling diseases Stem rot may be pre ented by spraying with bordeaux or a colloidal copper compound The exce si e use of nitrogenous fertilizers increases the incidence of tem di es es Root rot control requires the u e of crop rotati n and in some areas the u e of recentl developed varieties of *C capsularis* which are more tolerant to certain root rot pathogens than *C olitorius See* AGRICULTURAL SCIENCE (PLANT) PLANT DISEASE

[T E S]

Kale

E th of two cool a b i l rucifers (*B s ca l cea a a eph la* a d *B fimb i ta*) of Medit rr a o ig d bel ng g to th pl nt ord P p erale K le i grown for its nutr tiou gree c led le e Di tt t r t e re produced in Eur pe fo tock feed Kale a d colla d d f fer ly th f rm f the leave b th r minor eg t bles in the Un ted State C ltural pract e a e m l t tho u ed f cabbage b t k le is m t e t h gh temperatu es Strains of th Sc t h d S be n a tie e mo t p pul kal s mod tely t ler nt f acid o l M tl ly mea t mpe tur b low 70 F fa be t growth H rve t g i g erally 2 3 months fter pl t ng K g n i an imp rt t p oduc g tate Th t tal an u l farm lu i the United St tes i $740 000 *S e* CA B GE COLLARD PAPAVERALES VEGETA BLE GROWING. [H J C]

Kaliophilite

A m e al t to l c t f nd in ol r ck h gh n pot um nd l w s sil Kal ph l t s e of th ee p lymo ph f rm f $KAlSiO_4$ th the the r e m r l k l lit and n rtho h mb ph f rmed art fi lly at ab t 500 C. It y tall zes in the hexag al syst m pri m ti ty t l w th poo p i m t c a d b al l ge Th ha d 6 on M h cale a d the p fi gr t 61 At h gh tempe tu s a mplet sol d sol t s ex t bet n $KAlSiO_4$ and $NaAlSiO_4$ b t t low t mper t th s s i compl t Th pri p l urr n e f k li ph l te i t M nte Somma Italy *S e* SILICATE MINERALS [C S HU]

Kalsilite

A ra m l d r l d i 1942 from lc i ock t M f ru in so thwest Ug da K l il te h m b nth d It of th thr e polym ph f rm f $KAlSiO_4$ the th s r k l ph l te nd n orth h mb pha e f rm d t fi l at bo t 500 C. Th m al a h wn by phot ph i h g n l The p fi gr ity 2.59 In d of fra tio and ge al p- p th t t r mbl n ph l d d ffi lt t d t gui h f m t St t lly th tw m e al a mil b t b long to d ffer nt try t l l Th k wh h k l l t wa f d h a d k-col ed fi e-g ed m t x w th la g l ry tal d g n h y ll w patche These p t h r t t m t m i t f d p d l t d kal il t *S* FELD ATHOID [C S HU]

Kame

A hill f p o ly tratified and rt d glacial dr ft in or near an e d m ra or interl bat moraine The dep it wer f med i h le or cracks f the gl c r p rtly und r tanding water a h wn by incl ed bedding Melt ng of upporting i e w ll di turbed the b dding Kames are ommonly a oci ted in kn bby gr up with m ll feat r s te m d kettl appare tly l ft from the m lting of l c lly b ed bl ck f gl cial e



Kam i W Th m ll oc ot d d p ss m li t d b of p d g (USGS ph t)

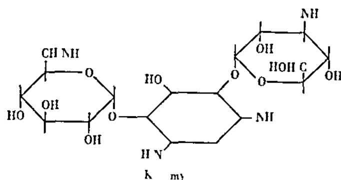
Th term k me ha been u ed l o ly and applied t hills ca d by stream ro t n of o twa h to p tted utwash or t ll d lta M ul kam e t k ng onical gr el fill ngs of h le m lted th gh i gn t i e *S* GLACIATED TERRANE [F T T]

Kanamycin

A ant biotic pr du ed by a p ev ly u de cribed sp c es f t n myc t *St pt myces k myc t u* d co r d I p by D H m o Umezawa a d w k Coll b ati e re ear h by Bri tol Labo t r es the Un t d St tes a d b J pane s nt t d ated u f l ga n t certa n or ga ms h h c e s me i cal probl m Th ncl de t phyl *c h* h a e e i t nt t othe mm ly ed a t b t c the tub cle b c l l s r t t t *ept myc* n a d i o t n c d h d zid nd me gr m eg tiv g n sm e pon bl f r u i ary t ct fecti n *S* ANTIBIOTIC ISONICOTINIC ACID HYDRAZIDE STREPTOMYCIN

Ch mi l t d e f k namy h e hown t be ate l bl tabl ba ant b t m

posed of three moieties These are 2 deoxystreptamine (a component of neomycin) 3 glucosamine and 6 glucosamine The latter two components are glycosidically attached to the deoxystreptamine and represent compounds not previously found in natural products



K my

The antibiotic has bactericidal activity for a wide variety of gram positive gram negative and acid fast bacteria Its antimicrobial spectrum is similar to that of neomycin (*see* NEOMYCIN) Organisms resistant to neomycin are also resistant to kanamycin and vice versa Resistance to kanamycin develops slowly in step wise fashion except for the mycobacteria which develop resistance rapidly

Kanamycin is far less toxic than neomycin both acutely and chronically when given by parenteral route (injected into the body) High dosages given for prolonged times to experimental animals can cause kidney vestibular and auditory damage Intramuscular injections result in high blood levels in one to two hours Kanamycin is also detectable in the cerebrospinal fluid When given orally the low blood levels obtained indicate that the antibiotic is poorly absorbed from the gastrointestinal tract

Clinical responses have been obtained with a variety of infections Staphylococcal infections accompanied by bacteremia (bacteria growing in the blood) have responded as have some urinary tract infections cau ed by a variety of organi ms including *Proteus* Treatment of urinary infections due to *Pseudomonas* has not been as successful Early tudies on chronic tuberculosi indicate u efulne when the organism is re istant to streptomycin and i onicotinic acid hydrazide Salmonella and shigella infections have al o been treated ucce fully Kanamycin has been u ed atisfactorily for pre operative bowel terilization by oral admini tration

Decrea ed auditory acuity (hearing) in the high frequency range ha been demon trated u ually only by audiometric mea urement Only a mall proportion of patient had subjecti e l and only rarely did complete deafne occur Decrea e in renal function ha occurred rarely and was ol erved to return to normal after topping treatment [J L]

Kangaroo

Any of everal species of Au tralian mar upial mammal of the family Macropodidae The same famil includes the tree kangaroo m u e kangaroos and wallabies Kangaroos are usually large weighing as much as 200 lb and are typically animals of the open country a habitat in which their jumping method of locomotion is frequently developed They have long powerful hind legs, and long mu cular tails Their front legs are hort and are used for locomotion only when moving about slowly as they graze They feed and travel in pair in family groups or in large bands


Kangaroo a marsupial

Kangaroos formerly were important a an item of diet in Australia but they have been o everely depleted for their hides which make good leather that they are no longer significant as food animal They compete with domestic stock for the forag on grazing lands and are given little or no protection *See* MARSUPIALIA [J D B]

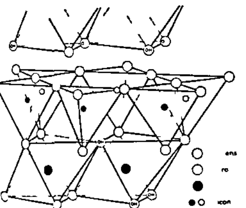
Kaolinite

The principal mineral of the kaolinite group of clay minerals Kaolinite is compo ed of a single silica tetrahedral sheet and a single alumina octahedral sheet These two units are combined so that a common layer is formed by the tips of the silica tetrahedrons and one layer of the octahedral sheet (Fig 1) *See* CLAY MINERALS

Kaolinite is of fundamental importance in the ceramics indu try becau e of it excellent firing propertie and refractorine s It is also u ed extensively a a filler in rubber products and for coating and filling paper products *See* CERAMIC TECHNOLOGY

Structure In the common tructural layer t o third of the atom become O instead of OH because they are shared by the silic n and aluminum The aluminum at m which are pre ent occupy only two-third of the po ible po itions in the octahedral sheet and are hexagonally di tributed in a ingle plan in the center of the sheet All charg within th tructural unit are balanced and the formul for ka linite i $(OH)_8Si\ Al\ O_1$ Any replacement within the lattice are of ery small magnitude

The heet unit of the ka linite mineral are c ntinu i in both the *a* and *b* cry tallographic d rec



g 1 D g mm t k t h f th t ct f th l n l y (F m R E G m Cl y M l gy McG -H ll 1953)

u Th y e tacked one abo e the ther in the d ecti with sup p t f O d OH planes dj c t units These units e h ld firmly together by hydrog b d ng

All kaol ites d t ha e the same order of rys- t llinity Poorly cry tall zed ka l ite re d o d ed l g the b is w th the t l ye randomly d pl d by m lt pl f b /3 The e poorly crys- t lli e v ri tes l h e l ghtly h ghe fi t rder sp c g th th w ll crystall zed mi e l Ka linit is su lly refe ed to a a 7 angstrom cl y min l beca e t fi st der b al pacing s l this app ox mat magn t de D ck t d nacrite altho gh ra ely found i cl y material h t c tures im la t k l n t They are comp d f th ame structural n t and d ff only i the sta king of the l yers. The u it ll of d ckite is mad p of two k olin te layers The n c te unit ll c mpo ed of unit lay s

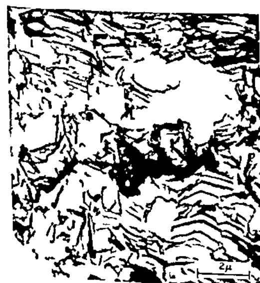


Fig 2 El ct m g ph f k l t M Geo g (F m R E G m Cl y M l gy M G w H ll 1953)

Morphology Electron micrographs of well crys- tall ed k olinite show well form d six sided flakes freq ently with an elongation in o e d rection (Fig 2) Part cles w th le s dist nct six sided flake ha e been b erved in p rly crystall zed kaolin ite The latter ha e ragged and irregul r edge and a very crude hexag al outline In ge eral poorly cry talli d kaol nite ccurs in maller par ticle than the well crystallized mine al

D ckite particle are very well fo med and have a disti ct hexag al outl e They d ffer from kao- linite i that they a e much large and can some- t mes be st d ed with a light m roscope

Na it part les are somewhat irregular rou ded fl ke- haped un ts. Some of them show a r de hex gonal outli e

Properties The mineral ka l te has a low cat ion exch nge capacity (5–15 milli quivalents per 100 g m) Broken bo d around the edges of the l ca al mina u t are the major cau e of this exch g apacity An n e change capa ity i also low except when t t ral hydroxyl are replaced or the a n is adsorbed because of its epita al fit The rate of the ha ge re ct n i e y rapid d th xchange cap city increases a the p ticle si e dec

Kaol nite contains no interlayer w ter betwee the t ll layer It d es h we er h e the ability to ads rb wat r and develop pl ticity Thi w t r has a defi ite config ati and is referred t nl q d w te

When kaolinites are heated they beg n to lo e their OH structural water at about 400 C with the dehyd t n b g complete at 550–600 C. The pr t mpe atu e for the l ss of this OH water ie f om kaolinite t kaolinite and may be ex plai ed by variation in particle size and crystal l ity The loss of OH water in poorly crystalli ed kaolinite is acc mp nied by a f irly complete loss of tr ct re but in well cry tallized ka li te s me tru t ral mna t persi t until subjected to h gher tempe t e

A sh rp e thermic re ctio c s at 950 C in p ly ystall ed kaol te The xpla at n for the th rmic r tio h s b n ttr buted t the f m t n f γ Al O by ome w k s d to th n cle t n of mullite by the Rece t wo k str gly fa o the l tter pla t n

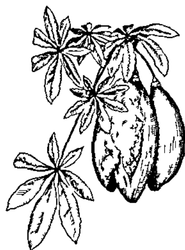
Formation Th k l nite typ f m e l forms d a d cond t at l w t mpe at e nd pr It c n f rm nder hyd th rm l d t thro gh th lt at n f th lay m eral K l te m y f rm fr m y co st tu t f the alk l es a d alk l e e th e r m d s fa t a th y libe t d f m the p nt rock or f the e m t s d d the t mp t e mod at It a p i pal c mp t f late t type l Wh cal um pre e t the e i o m t th f rm t o f k l ite i r t ded

Th p e t day m e me t d n t fa th f mat n f k ol t The p ese f a k l t m r ed me t i d f k ol n t e a e th m l d not form

in the ea It is also indicative of relatively rapid accumulation of material *See* CLAY COMMERCIAL [F M W R F GR]

Kapok tree

The kapok or silk cotton tree *Ceiba pentandra* is a member of the bombax family (*Bombacaceae*) The tree has a bizarre growth habit and produces pods containing seeds covered with silky hairs called silk cotton It occurs in the *American trop*

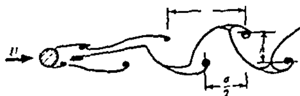


Pods and lea es of kapok tree (Ce ba pentandra) (From E L Palme Feldbook of Natural H story McG aw H ll 1949)

ics Java I hilippine Islands and Ceylon The silk cotton is the commercial kapok used for stuffing cushions mattre ses and pillows Kapok has a very low specific gravity and is impervious to water consequently it is excellent material for filling life pre ervers and other similar equipment *See* MAL VALES [P D S]

Karman vortex street

A double row of line vortices in a fluid Under certain conditions a Karman vortex street is shed in the wake of bluff cylindrical bodies when the relative fluid velocity is perpendicular to the generators of the cylinder as illu trated This periodic shedding of eddies occurs first from one side of the body and then from the other an unusual phenomenon becau e the oncoming flow may be perfectly steady Vortex streets can often be seen for example in rivers down tream of the columns supp rting a bridge The treet have be n studied mo t completely for circular cylinders at low sub onic flow speeds Regular perfectly periodic eddy shedding occurs in the range of Reynolds numbers Re based on cylinder diameter from 50–300 Abo e Re of 300 a degree of randomne s begins to occur in the shedding and becomes progre sively grea as Re increases until finally the wake is completely turbulent The highe t Re at which ome light periodicity is still pre ent in the turbulent wake about 10^6



Ka ma ort st eet

Vortex streets can be created by teady wind blowing past smoke stacks tran mi sion lines bridges missiles about to be launched verti all and pipe lines above ground in the de ert The streets give rise to oscillating lateral forces on the shedding body If the vortex hedding frequency near a natural vibration frequency of the body the resonant respon e may cau e structural damage The Aeolian tones or singing of wires in a wind an example of a forced oscillation due to a vortex street T von Karman showed that an idealized infinitely long vortex street is stable to small di turbance if the spacing of the vortices is uch th $h/a = 0.281$ actual spacing are clo e to thi valu A complete and satisfying explanation of the formation of vortex streets ha however not yet bee given For $10 < Re < 10$ the shedding frequenc f for a circular cylinder in low ub onic peed fl is given closely by $fd/U = 21$ where d is the cylinder diameter and U is stream speed h/a is approximately 1 7 A Roshko discovered a spanwi e p riodicity of vortex hedding on a circular cylinder $Re = 80$ of about 18 diameters thus it appear that the line vorti es are not quite parallel to th cylind r axis *See* FLUID FLOW PRINCIPLES VOR TEX [A E BR

Bibliography A Ro hko On the wake and dra of bluff bodies *J Aeronaut Sci* 22(2) 124–13 1955

Karst topography

Characteri tic a ociations of minor third order destructively de eloped land features re ulting from sub aerial and underground solution o lime tone under conditions of humid climate Th pattern features are progres i ely carved int econd order structural form such as plains plateau r e en hilly and mountain us upland containing lime tone layers at or near the surface Virtually all lime tone formations are products o biological or chemical precipitation of calcium carbonate $CaCO_3$ from aqueous soluti n They are therefore su ceptible to varying degree to resolution in surface and gr und waters parti u larly when such waters are charged with carbon dioxide CO_2 from vegetative sources or when the waters are under pre sure *Se* LIMESTONE

Fa oring c mbination of the factors in I ed produce a land cape unlike tho e re ulting from other agents of land sculpture Where a kar t topography ha d el ped m t surface water dis appears quickly by entering inkhole and oth r entran e ways into undergr und tube pa ag s and cavern that are enlarging becau e of th

presence d p ag f the e water M st tr am —ge lly all b t f w t u k t eams in the deeper valleys—are h rt nd c ce ill d fi d ll nd ab ptly nk or s allow h les The l ck of a rfac t m ystem i re flected in h ll thout th l ne di ide a d in terr ll y h acter of m lly tre m er ded re g ns Th ame k t is t ken from th regi nal des gn t n f c a t l zone of h ll a d l w moun tai l g the n rthe tern ho e of the Ad i t c Sea In th eg n of l me t e ck the land pe lv e rywh e ch cter d by a pred m n nce f sol t on m de topogr phy



S kh l M d C ty K D pth t d gro d w t b t 50 ft (U S G l g l S rv y)

Sinkhole types Tw tr ted typ f s nk holes th d l n nd the p may b pr ent

D l A d l e a a c haped l to m d dep es i n c mm ly c ll d kh le per h p h dred f fe t n d met w th l co ed l pes It gen lly h s n p n entra c t the derg o nd a d u lly doe t d h ge nt an t r bl The b ttom m y be ffici tly l gged with w t t m ta n a p d fo y ar th n may bruptly l ll its w te e b pt d ng lp

P no typ The g lly r ult f m l cal f l f a l t n-ch mbe oof wh e llaps p od the f e pon nkhol Th s typ t d t be teeply w ll d mm ly with b r rock, a d l d to a c la ge en gh t h dev l ped t b l ty f r ck Co l e e f h c ll pse p i m y tu lly xp e mo t f th l rme a t th rth f ce w th em nt port f th oof om pl s t l bridge r tu el A f e ll y wh ch by d nce c ed th f x t ng m y ha t t am wall ed d wn by fo mat f a p r d th bec m s king ek lost R t rn f th t m w t t f d g l k ly al g som m j r r lley lt th pp r u g wh h t b d d ntam ted l ke pri g f filt ed gr d w t

Soil lapiés and shore conditions In a kar t topogr phy much lime t e i dis l ed l y ra n and l w ter before r ff eache inkholes r streamw ys In oluble t tuent like cl y and grain d cl ert nod le may remain n gentler l pe a a c ntinually thi kening co er of re d al l aptly n med t rr r a fr m t red c l

Contact f uch l with the derlying lime t e i gener lly harp d may be ery irreg lar be au of varying tr cture i the rock aria tion uppl of water and ar d ol bility of the rock If er n trip off thi il m ntle m ture k t may ome t l ght a luti made urface with r l ef of a few i ches t a few feet th t i k wn a l pi E en withot t a il c e th attack f ra n and ow water can produce a k d f l pi

Sea water ev n when atur ted w th CaCO may p odu ragged lap rface on lime tone h re l that are ul ject t c tant wa wa h This may be a r ult f l ght ch nge in temperat re a d pre ure in b eaki g wa e Mar ne alg e g w g o t h wa e wept urf c m v al be a f i g fa t

Related features A kh le iddled urfa e i n lcareous ock m v r lt fr m exten e g nd wate l tio in ubj ce t l m t ne r d lom t Con que t s b id c of the o erlyi g l bl o k i t d pres oc ur with lu ti l mo l Thi mm nly t rmed oluti n b d nc th fill d it es ne er ha ing be n pe a n E the p ti l remo al of buried b d f gyps m d k lt m y imil rly p odu a olut al ub de c top graphy

Cyclical landform development The eq n e f h ng i la df m f kar t r g ons from nit a t n f s kh l th ugh tag f th r i cr a mb l gem nt a d ales e c w th col l p f er d e nt l w st ng way of terve ng hill lea s br ad b ttomed lowland (u la) nd catt d urv ing lev ti n Al th gh thi ka t ycl i st ll ubje t to theo etic l deb te th c pt eem alid be u e d ffer nt t g s f land f m de l pm nt e ide t fiable i a s k r t f d ff g ge

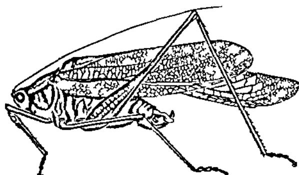
Not w thy k r t g a rel t ly u om m in sp te f te v l mest e te r i s th l ds f the e th The b st how ngs in E r pe e th K rst a e f Yugo l i the Ca s e re g n f F d a C e e a d Andal s a N th Am r c n e mple ar f nd n thern Yu t n nt l Fl r da, the Appal ch n G e t Vall y T e s e d V gi i i uth rn Ind d w t-ce t al Ke tucky J ma a P rto R c nd C b al o h e well-d l ped k t S CAVE GEOMORPHOLOGY GROU D W TER WEATH R G ROCESSES [J H B]

B bl g phy A H D err and D R Hoy K st l d p of Cub P rt R a d Ja m *Th Sci t fi M thly* O t 19 7 v l 85 n 4 W D Th nb y *Pri ciple of G m ph l gy* 19 4 O D on E g In *G m phology* 1942

Katydid

Any of several bright green long winged grasshoppers of the family Tettigoniidae order Orthoptera The katydids occur throughout the Northern Hemisphere They are mainly herbivorous although there are a few carnivorous species Katydids are rarely of any economic importance although occasionally they may defoliate trees

The long antennae longer than the body are characteristic of the katydids and others of this family in contrast to the short antennae of the true locusts of the family Acrididae



The forked tailed bush katyd d *Scudde ia furcata* le gth to 2 in (F m E L Palme *Fieldbook f Nat al H story* McGraw H ll 1949)

In temperate climates katydids overwinter in the egg Eggs are usually deposited on twigs under bark or by splitting the edge of a leaf and placing the eggs in the slit *See* GRASSHOPPER ORTHOPTERA [J D B]

Kelvin bridge

A specialized version of the Wheatstone bridge network designed to eliminate or greatly reduce the effect of lead and contact resistance and thus permit accurate measurement of low resistance The circuit shown in the figure accomplishes this by effectively placing relatively high resistance ratio arms in series with the potential leads and contacts of the low resistance standards and the unknown resistance In this circuit R_A and R_B are the main ratio resistors R and R_b the auxiliary ratio R the unknown R the standard and R a heavy copper yoke of low resistance connected between the unknown and standard resistors

By applying a delta wye transformation to the network consisting of R R_b and R the equivalent Wheatstone bridge network shown in the illustration is obtained where

$$R = \frac{R\,R}{R + R + R_b}$$

$$R = \frac{R\,R_b}{R + R + R_b}$$

$$R = \frac{R\,R_b}{R + R + R_b}$$

By an analy is similar to that for the Wheat tone bridge it can be shown that for a balanced bridge

$$R = \frac{R_B}{R_A}R + R\left(\frac{R_b}{R + R_b + R}\right)\left(\frac{R_B}{R_A} - \frac{R_b}{R}\right) \quad (1)$$

If

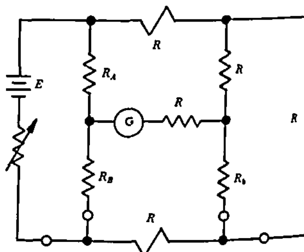
$$\frac{R_B}{R_A} = \frac{R_b}{R} \quad (2)$$

the second term of Eq (1) is zero the mea urement is independent of R_y and

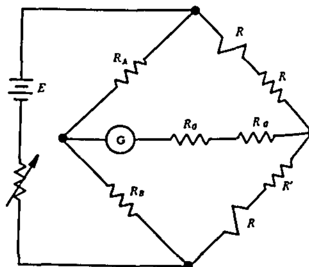
$$R = \frac{R_B}{R_A}R \quad (3)$$

As with the Wheatstone bridge the Kelvin bridge for routine engineering measurements is constructed using both adjustable ratio arms and adjustable standards However the ratio is usually continuously adjustable over a short span and the standard is adjustable in appropriate steps to cover the required range *See* WHEATSTONE BRIDGE.

Sensitivity The Kelvin bridge sensitivity can be calculated similarly to the Wheatstone bridge The



( )



(b)

K l bridge ( ) Actual ci c it (b) Equi al t Wh at sto b dg ci c it

open-circu t, bal ce v ltage ppe ing t the d tect termi als may be expre ed to a l se d gree f app m tion as

$$e = E \frac{}{(+ 1)^2} \left[\frac{\Delta R}{R + R \left(\frac{}{r + 1} \right)} \right] \quad (4)$$

The unb l nce d tect curr t for clo ed detect cir t m y be e pre d app ximat ly a

$$I_G = \frac{E\left(\frac{\Delta R}{R}\right)}{\frac{R_G}{(+ 1)} + R_A + R_B + R + R_b} \quad (5)$$

Th K l n b idge requ power pply pa bl of d l er g r l t ely large c ent d ing the tim a me me t i be ng m de The total lt g ppl ed t the bridge s u ally l m ted by the pow r d pat capab l ti s f the standard and k wn es st r

Errors K lvin br dg re st e-m u eme t er r rs a e ed by the me fact rs s f r the Whe tst bridge H w e add t n l so rce of rror impl ed by the second t rm of Eq (1) m t b eval ted e th e fa t w ll eld m be red ced to e o F r m n m m e r the y k res t n h ld b m d a l w s po bl by phy lly pl c g the mm ly c ne ted c e t t rm] f th u kn wn d t nd rd a clo together a pos bl d c e t ng w th a l w re s ta e l d

The rat r t s h l de t lv th es t ce of th res t s b t l that of th i ter on ect g wi ing d ext n l leads nd th co t r ta of th p te t l i t t ct Th term l l d re mo t l kely t ca e r and they hould th ef e b f th am r ist n e so that Eq (2) ill be f lfilled a n aly as p sbl I add t n they h ld be el t ely hort n e the add t o f la g est ta c (lo g l ds) will int od e o n the l b ted t R_B/R F p m u ment t mm dju tme ts a qu ed the r ti arm r t nd p m d t e t th b dge re t int tw d ffe t Wh at t e b dg n figu ati s. By i ly b la g fi t th K l n n t k d th n h of th Wh t t t k thes dd t e r rt lly el m n ted S BR CE CIRCUIT RESISTAN E M EASURE MENT [C A]

Kelvin s circulation theorem

A theo m fl d dyn m th t p rt s t a n mp es ble i c d fl d A d t n q f th theo m gr t mpl fi t n unde t d g d ly g a l g cl of fl d fl w lled rr t t nal fl w (BE NOULLI S THEO-R M LAPLACE S I ROTATIONAL MOTIO) The l t Γ bo t l ed rv in fl d d fi d th l e t t g l f the mpo e t f l ty l g th t

$$\Gamma = \oint \quad d$$

whe e v i the fluid eloc ty and ds is a length element al ng the urve (Ci culati n be rs a strong anal gy t the work done in mo ng a part cle around a cl sed curve in a f ce fi ld) Kel i s theor m states that in an inc mpressible in cid fl d the cir ulati n al ng a cl ed urve alw ys c nsi t ng f the same fluid particles does not hange with time An imp rtant co equence of thi the em relates to fluid motions starting f om rest or unif rm motion i such fl ws the cir ulat on is nitially ze o f r e ery po ble closed curve and h nc r mains q l t zer the eafter c rd ng to Kel in s theorem This impl es th t the l ne integral of the velocity taken from fi ed po nt A to fixed p i t B is indepe dent of the path from A to B Con ider for example tw differe t path C and C fr m A t B then $C - C$ forms a cl d ont ur a d the l ne in tegr l ro d it an shes showing th t the l ne int gr ls lo g C a d C re equal If the line i tegr l is i dependent of path the integ a d mu t be a pe fe t diff e tial that s the velocity mu t equ l the grad e t f some sc la funct on $\mathbf{v} = \nabla\phi$ so th t

$$\int_A^B \quad d = \int_A^B \nabla\phi \;\; d = \phi \; - \phi_A$$

whe e ϕ i called the el city potential a d is a f n ti f p it n i the fluid nd time $\phi = \phi(\mathbf{r},t)$ Be u e

$$\text{u l } \mathbf{v} = \text{curl (gr d } \phi) = 0$$

the fluid mot on i i tat onal The fl id moti n is al o d erg c f e (ole o dal) f m sid a ti n of o t ity (s FLUID-FLOW PRINCIPLES) Thu t foll w that d $\mathbf{v}$ = d (grad ϕ) = 0 wh h L pl ce equ ti [A E BR]

Kelvin s minimum energy theorem

A p i ipl of fluid mech ni wh ch state th t the r t t n l m t o f an in ompre sible in d fl d occupyi g a mply on ect d g on h le k et c e rgy th n a y the fl d m t n o t t with the bo d ry d t on f ze o r l t e el ty n rm l t the bou da es f th g n Th r m kable th o em is e sily p ed f ll ws Let T be the ki tic en gy f the i t t l m t n w th el city p t tal ϕ (s D ALE BERT S PARADOX LAPLACE S IRROTATIONAL MOTION) L t T b th k t c ergy f an the m t n with eloc ty fi ld $\mathbf{v} = \nabla\phi + \mathbf{v}$ F om c nt u ty t f llow that $\nabla \;\; = 0$ nd f m the bo nd y nd ti n $\mathbf{v}_0 = 0$ on th b u dary wh r n t e t rmal t the bo ndary u fac It f ll w that

$$T = T + \frac{\rho}{2} \iiint {}_0 \quad d \; + \rho \iiint {}_0 \;\; \nabla\phi \, d$$

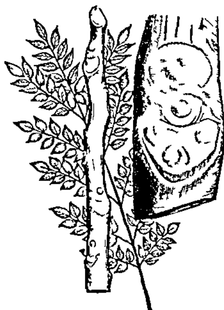
H e $_0 \; \nabla\phi = \nabla \;\; \phi$ bec se $\phi \, \nabla \;\; = 0$ and pply G d g n e the rem t the last t gr l abo t be mes

$$\rho \iint \phi \;\; {}_0 \;\; n \, dA$$

which vani hes because v₀ n = 0 on the bound ary The second integral above is a positive quan tity because its integrand is everywhere positive thus proving that $T_1 > T$ *See* FLUID FLOW PRIN CIPLES [A E BR]

Kentucky coffeetree

A large strikingly distinct tree *Gymnocladus dioica* which usually grows to 80–90 ft but some times attains a height of 110 ft and a diameter of



Kentucky coffeetree *Gym lodus d oica* (A H G aves *Illustrated Gu d t T ees a d Shrubs* Har pe 1956)

5 ft The species name *dioica* means that the tree is dioecious that i male and female flowers are on different individuals It grows from ea tern Nebraska Kan as and Oklahoma to outhern On tario we tern New York and Pennsyl ania and outhwe tward to Loui iana It can readily le recognized when in fruit l y it leguminou pod containing hard heavy red brown eed which were u ed by early ettler a a ul tit ite for coffee hence the name coffeetree The l ranch are stout and thick and the l ark ha thin twi ted ridge The leave are twice pinnate and the winter buds sunken in the l ark are uperp ed two r three t gether Ne er a c mmon tree it i me times cultivated in park and garden of the ea t ern United State and n rthern and central Eu r pe It is sometime u ed a a treet tree The w o l i hard reddi h and u ed f r con tr icti n It i durable in contact with the il and i al u e l f r railroad tie and fencepo t *See* FOREST AND FOR ESTRY TREE [A H G]

Keratitis

Any inflammation invol ing the cornea of the y It may involve the cornea alone (keratiti) r m re commonly both cornea and conjuncti a (kerato-conjunctiviti) *The variou f rm of keratit an l* keratoconjuncti iti t g ther c n titute a m j r porti n of all eye di ea e Fortunately many f rm

are not evere and do not re ult in vi ual impair ment nevertheless keratitis is a di ea e of maj r importance being second only to cataract and equal to glaucoma as a cau e of blindnes

Corneal structure and injuries *The outer ur* face of the cornea is covered by a delicate mem brane (epithelium) compo ed of flattened epithe lial cells and clo ely re eml ling the mucou mem brane lining the nasal pas ages and mouth The substance (stroma) of the cornea is compo ed of interlacing layers of collagen fibrils imilar to those een in tendons ligament and other connec tive ti sues of the body but more regularly ar ranged It is thi regularity of tructure that gi es to the cornea its property of optical tran parenc *Any alteration of this tructural regularity* due to destruction of the epithelium or troma or to the presence of pus edema fluid or car formati n re sults in an opaque region in the affected portion of the cornea

Such an opacity will usually be temporary if the injury i limited to the epithelium l ut permanent if the troma is al o damaged Although the re pon e of the cornea to injury is imilar in many re pects to that of other body ti ue it i m di fied l y the fact that the normal cornea d e n t contain blood ve el Blood ve els from the ur rounding conjunctiva are timulated to grow into the cornea only if injury i evere enough to cau e de truction and swelling of the corneal troma Since car formation requires the pre ence of bl od ve el this means that injurie of only the epithe lial meml rane ordinarily heal with ut carring In uch ca es healing occur by growth and pread of epitl elial cell from adjacent uninjured zones o er the injured area leaving little or no re idual opac ity These epithelial cell have a remarkable capac ity f r uch growth and can completely rec er the entire cornea within a few day *Deeper injuries* whi h cau e ingrowth of l lood ve els leave a per manent mark in the form of a scar vi ible a a gray white opaque region in the cornea The degree of i ual impairment i determined l y the p iti n a well a the ize of the car

Etiology Keratiti may l e cau ed l y mechanical injury infectious agent (l acteria viru e fungi pr t zoa) extreme of heat or c ld drying radia ti n corr ive or irritating chemical allergy or may o ur in a o iati n with di ea e affe ting th entir l ody u h a itamin defi iency Keratit al frequ ntly accompani ther di a e affect ing the eye uch a gla oma *See* CI AUCOMA

Sin e the c rnea r a t t injury in nl two l a ic way eitl r l y regr wth of epithelium in uperf ial inj ri or l y varying degrees of scar formati n in more ere injurie the degree of p rmane t imp airm nt of i i n i l termine l pri marily l y tl e extent of th injury ratl er than l y the natur of tl e injurio ag nt Of tl e vari u agent l act ria ar tl mo t imp rt nt since a c rnea in j r l l y a y m tl d i particularly s i eptil l t up rimpo d l act r l inf ti n frequently result ing in dam g f r great r tha initial njury *S e* EYE EYE I I ORDER [W R AD]

Keratoconjunctivitis (epidemic)

A al di e e ch r t z d by n acute conjunc u iti follo ed by keratiti wh h in me ca es lea es r nd sup rfici l opacities in the c rnea f r up t 2 y r It i al o kn wn as hipyard eye The u l al ag nt deno ir typ 8 Diag is m de by olati n f rus from ul r e- cr ti ns inoc l ted int t s ue It re r by th dem n t at n of nt body e ponses i the blo d *S A* TIBODY

Spo di es nd ep d m c h e occurr d in ma y c untries p rt c l rly in h pya d and in d trial pl ts Th mod f pread is n t po i ti ely kno n R gid a ep is in m dical di ion I nd t ial in t tut s re ommended t p e ent po ble p ead by med cal att ndant r by n trume t *Se* ADE OVIRUS ANIMAL VIRUS

[J L M]

Kerogen

A ame g en to the c mpl x rgani matt r pr s- ent n c rbo ceo s h les and oil hal It is n sol bl ll c mm ol ent b t on de t uct d t ll t y elds o l g s a d cidic d ba comp nd Ker g s f m d by the b hem al and dy am hemi al e *n of pla t and ani* mal rem in both m y be pr e t n r riable pro- porti n It i the m t comm fo m of o ga carbo earth and t h s be t m ted th t th e i 1000 tim s m ch l ge a al Be a se f ts di r fi d or g ker ge ar es n mposit n con t f pp im tely 7 –83% a bon 5–10% hyd gen 10–15% xyg and a mall p r t ge of t ogen *Se* OIL SHALE

[J A B]

Kerosine

Th r fi ed p t ole m fra t mpl yed a f l f lamps, jet eng n and m ll h t g appli a es, ch a c ok ng to f which g s l ne i su tabl K n is d till d f om the fr c t n ol n rm l crud oil bo l g betwe n 350 nd 5 0 F It r fin d to have p cific gr ity of abo t 0 80 nd t ma n l qu d t about –25 F Th chem l makeup s p tty well l m ted t the st ble p r ffin a d aphthe e (C to C) Th pec f t are r g d th rwi the mate- n l w ll not perf rm t fa to ly F t e th hydroc rbon m ke p m t be p affi c t avo d m ky fl m th c ty mu t b b ut po ses t ll w t fact ry f ed g by w k th n t of l t l mp t e wh h would l g the w ek m t be l w nd the lfur n t t m t b les tha 0 2% To edu e e plo- io h za d a fl h p nt f b ut 120–140 F pec fied.

K ros h s m sc ll neo e h fly s a sol ent f r ect c des It i w del ed a f l f j t ng s and met m recip c t g eng f l About 5% f the w ld de l p od t n, 2 5 000 000 l r l p r y ol l s k S D TILL TE FU L PETROLEUM PROD- UCTS

[M S O]

Kerr effect

When a sub tan e i pl ced in an electric field it molecule may bec me p rtly oriented This make the s b tance ani ot op c and gi es it b f n genc th t is the ab l ty t refract l ght d fferentl in tw d ection Tl is ele trically i duced birefrin gence di ered in 1875 by J K rr is called the ele t oopti l Kerr effe t or simply th Kerr effect (F r di cu n of the m g etoopti l Kerr ff t see MAGNETOOPTICS) Thi effect mu t be differen tiated from bir fringence d to mechanical t ain produced i l ds by an electric field The Ke r ef fect cry tal s omet mes called the Pockels effect

When a l quid i placed n an electric field it be- ha es optically l ke unia l ry tal w th the optic l axi parall l to the ele tric l es of forc The K effe t is u ally l erved by pa i g light between two o den plat s i rted in gla s cell ntai ng the liqu d S h a d ice i known as a Ke r cell There are two p ncip l *indic s of* efra t n *n* nd *n* (k own th rd n ry nd ex tr rdinary ind ce) and the sub t nce i alled a p sit v ly o n gat ely birefringent ub ta e de- pend ng n wh ther *n* — is po ti e or neg ti

L ght pas i g through the med um no m l t th lect line of force (th t i pa llel t the co *den plates*) i *split* nto two line rly p la ed wa es t vel g w th the veloc ti *c/n* a d *c/* respe ti ely wh re c is the veloc ty of light a d with th elect ic ector bratin p rpendicula nd p r llel t the l ne of force

The d ffe e n pr pag tion locity c u es a ph e d ffe en δ betwe the two wa s wh ch *fo* m no hr mat l ght of wa el gth λ_0 is $\delta = (-)x/\lambda_0$ wh re *x* i the l *ngth* f the l ght path in the m d um

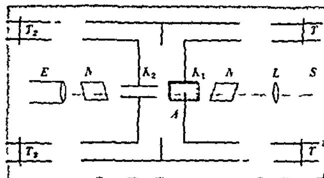
Kerr constant Ke fou d mp r cally that $(n - n) = \lambda_0 BE$ wher *F* is the elect field st ength nd *B* a c t t ch racteri ti of th ma te ial lled th Kerr tant Ha el ck law st te *th t* $B\lambda n/(n-1) = k$ wh *n* i th re fr ti e i de f the *ub tan e* the ab e f th fi ld a d *k* a c st nt ch r cte ist f th *ub t n* b t depend t of th wa el ngth λ *Ro ghly speak ng th* Ke r co stant i inve ly *pr p t nal t* the b l te temp atur Th ph s d ffe e e δ i d t rm ned xper me t lly by *tand rd opt l tech* que If the w length λ i e pre sed in ntim te a d th field *t ength* *E* in t t lt /cm (1 st t lt = 300 lt) *the* Kerr co tant f c b d lfide wh ch h been *determ* ed n st ac u ately is *B* = 3 226 × 10- V *lu of B* r ge f om –23 00 × 10- f r pa l dehyd t +346 0 × 10- f n t b n)

Th the ry f the Kerr *ffect i* b ed n th fact that nd vidual mole ul a n t l ctr ally o- tr p but h e p rm t o i d d el t c di pol The electr field t d t i nt thes di pol s wh l th n *rmal* th rm l ag tati t d to de troy the r t i on Th *b l* nc that i tr k dep nd on the z f th d *pole* m m nt th mag t d f th le tr f ld d th

This theory accounts well for the observed proper ties of the Kerr effect

In crystals which are electrically polarized there may be changes in the refractive properties that are proportional to the first power of the electric field strength (Pockels effect) Such crystals also exhibit piezoelectric properties The situation is made more complicated by the fact that in such crystal the index of refraction is represented by a tensor of the econd rank and there may be in a general ca e 18 linear electrooptical constants New crystals show ing the Kerr effect have been used extensively for electrooptical shutters and birefringent filters The Kerr effect here is independent of the piezoelectric deformation of the crystal which also may produce changes in the optical behavior

Electrooptical shutter When a Kerr cell is placed between cros ed nicol pri ms so that the planes of polarization are 45 inclined to the axis of the conden er no light will pass so long as the conden er is not charged When an electric field is applied there is a rotation of the plane of polariza *tion and light is transmitted by the econd pri m* Since the orientation of the molecules in the liquid on which the effect depends is effected in times of the order of magnitude 10 sec the shutter opens or closes in thi interval The time and duration of electrical pul es which control the shutter can be controlled by suitable electric circuits

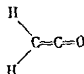


Kerr cell shutter (after Beams) S i the l ght sou ce N_1 and N are c ossed nicol p ms K a d K_2 a e c ossed Kerr cells E is a photo ece A s a pa k gap and T_1 and T a e adj stments fo the le gth of the wire loops

The tim to charge a conden er is u ually con siderably longer than 10 sec J W Beams con structed a *econd version* of the electrooptical shut ter which can open and clo e abruptly It employs two identical Kerr cells K_1 and K_2 with the axes placed at right angle The electric double refrac tion in K_1 is exactly compen ated by that of K_2 as long as identical *field are applied* to the two c n den ers The cond nser are discharged uddenly through a spark gap A but wires of different length connecting the spark gap with the cond n ers cau e the field breakdown to arri e at different times at K_1 and K_2 During this *very short interval* of imbalance light is tran mitted Kerr cell shut ters have been u ed for the study of events requir ... high time re olution [C H D]

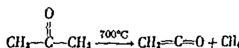
Ketene

A colorle s highly reactive gas boiling point −56 C melting point −151 C. It is oluble in ether and acetone and it decompo e in water and alcohol The ketene molecul

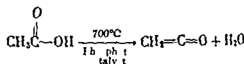


contains on of the most reactive carbon l groups (> C=O) known

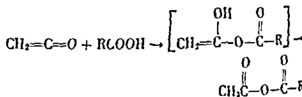
Ketene is produced by the pyrolysi of acetone vapor



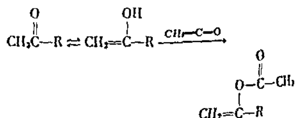
or of acetic acid vapor



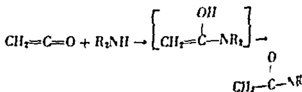
Carboxylic acids add to ketene to give acid anhy drides and this is the basis of an important com mercial process for the manufacture of acetic an



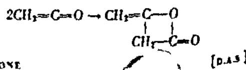
hydride Ketene reacts with the en l f rm of ket ... to produce enol acetates



Molecules containing O—H or N—H bonds add to the carb nyl group for example



Dimerization of ketene to diketene occurs on s ... age of ketene even at low temperature



See KETONE [D A S]

Ketone

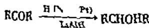
One of a cla s of chemical ompounds of gen ral f rmula RCOR wh e R and R are alkyl aryl or hetero yclic adicals The groups R and R may b the sam r d ff rent or in orporated int a g a in CH CH CH CH C=O (cyclopentanone)

Th k t s acetone and methyl ethyl ketone are used a sol e ts Other ket nes re imp rtant a interm di tes in the synthe es of organ c com pou ds.

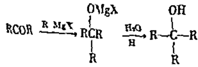
By comm n nomenclature rul s, the R and R groups ar n m d followed by the wo d keto e f r e ample $CH_3CH\ COCH_2CH_3$ (d ethyl keto e) *CH COCH(CH)*$_2$ (methyl is pr pyl ketone) $C_6H_5COC_6H_5$ (d ph nyl ket ne) IUC nom ncla tur the me of th hydroca bon c rre p d ing t th maximum n mbe of ca bon atoms i co ti u u chai in the ketone molecule f l l *ed by* on and pre ed d by a numb r desig ti g th p t o f the carbonyl gr p in the c rbo h in. This gi e th names 3-pentan n and 3-methyl but non f r the first two ket nes abo e.

React ons of ketones Addition to th c rbon l group i the m st imp rtant type of ketone e c t n Ket nes re gen lly le s eact tha alde-h des n dditon s tio s b t th methyl keton s (R o R = CH) a e apprec bly more e ct e than th r ket Th s eems due to the s z and st ri ffects f the atta hed gro p

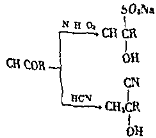
Hyd ogen dds *catalyt c* lly to th c rbo yl gro p d *l th um* alumi um hydr d gi es the same typ f prod t n mely th seco dary l o-h l The G ig rd e gent dd to the ca b nyl



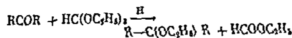
gr p and tertiary alc hol e f med by hydr l y of th additi n p duct



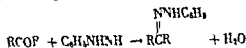
The Refo m tsky reag nt XZnCH COOR r act the Hyd g n yan de nd od um b sulfite will add to m thyl keton



Al hol d not add eadily to the k t ne c rbonyl a they do to th ald hyd ca bonyl, b t ketals may be f rmed by th act n f rth f rmates



Amine deri at ves such as hydroxylamine (NH_2OH) phenylhydrazine ($C_6H_5NHNH_2$) and semicarbazide ($NH\ CONHNH_2$) add to the carbonyl by breaking n N—H bond and with sub equent loss of water Th re ulti g oximes phenylhyd azone and semi

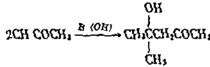


carbazo es are u eful de ivati es for the ident fica tio and chara ter zat on of ketone

Ketone supply alpha hyd og n in ald l type con den t n reacti ns but can supply a carbonyl *group o ly to l mited extent d ie to* ts lower re activity



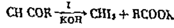
An xception i the elf-c ndensation of acetone to diacetone alcohol



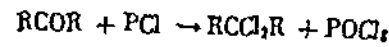
The low r cycl c ketones generally h e more re-act e carbonyl gr ups f r ll react ons due t the e posed p sition f th group nd to the rig d ty of the ng

Ket nes re xidized l s read ly nd less selec t ely than ldehyde to give ox d tion products h a c rbo ylic acids by cleavag f th b nds fr m the arbo yl ca b n at m to the adjace t tom They fail t g e the T llen and *Fehli g s* t sts although α hydroxy ketones will gi e the t sts

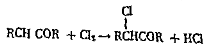
Methyl ketones gi e the haloform *reaction with* lut o s f od e n aque us p t ssium hyd ox de



The oxyg n atom f the carbonyl *gro p of* ke-to e may be r plac d by two hl rin atom by tr atme t with ph pho u penta hl id PCl_5 lth ugh in g n ral the yield are poor

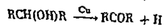


Chlo in o b omine will bstit t the alpha hy drog n at ms of keton s Th r ulting α hal ke-



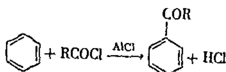
t n a q ite rea t e in d splacement reacti n f the h l g n atom.

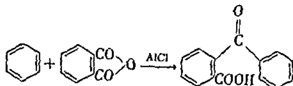
Preparation of ketones Th d hydrog nati n or x dati f s condary al hol at el ted tem p rat r yi lds k t s nd this i a alu ble com mer al method whe th secondary alc h l is f



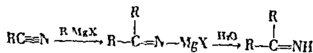
low cost as for example tho e obtained by olefin hydration

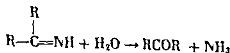
Aromatic ketones may be prepared by the Friedel Crafts reaction by acylation with acid halides or anhydrides



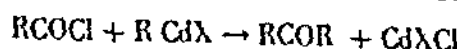


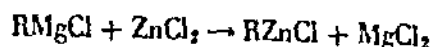
The Grignard reagent adds to nitriles to give ketimines which form ketones on hydrolysis



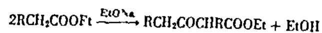


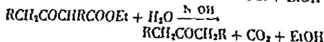
Organozinc and organocadmium reagents give ketones upon reaction with acid halides The e organometallic compounds are best prepared from the Grignard reagent and the metal halide



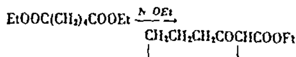


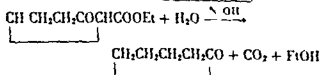
Beta ketoesters formed in the Clai en condensation are cleaved by aqueous sodium hydroxide olution to form ketones



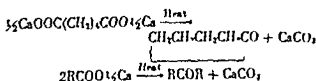


The Dieckmann condensation of esters of dibasic acids leads in imilar fa hion to cyclic ketones

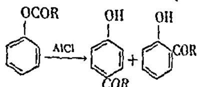




Both cyclic and open chain ketone are formed by pyroly is of calcium or thorium salt f dil a ic acids or monoba ic acids



E ters of phenols rearrange when heated with aluminum chl ride t i f rm phenyl k t n (Fries rearrangement) in which the carbonyl group is ortho or para to a phenolic hydroxyl See Aldehyde



HYDE CONDENSATION REACTION FRIEDEL CRAFTS REACTION GRIGNARD REACTION HALOFORM REACTION REFORMATSKY REACTION STERIC EFFECT (CHEMICAL REACTIONS) [D.S.S.]

Bibliography R Adams (ed) *Organic Reactions* vol 5 and 8 1949 and 1954 C. R Noller *Chemistry of Organic Compounds* 2d ed 195

Ketosis

An excessive accumulation of ketone bodies in the tissues blood and urine Ketone bodie are acetacetic acid β hydroxybutyric acid and acetone all of which are formed by the oxidation of fatty acid by the liver See KETONE

When a disturbance in carbohydrate metabolism is present ketone bodies are produced in exces This results when the ti sue requirement for energy are not met by a readily availal le or utilizable supply of glucose Fat and protein mu t then be mobilized to the liver which transforms the e substances into gluco e a proce s called gluconeogenesis In the eries of bi chemical hifts involved fatty acids are oxidized in large am unt o that their normal breakdown product the ketone bodies accumulate See CARBOHYDRATE CARBOHYDRATE METABOLISM GLUCOSE

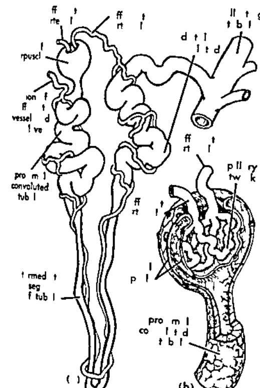
The ketone bodie by virtue of their acid properties hold an equivalent amount of ba e thus producing a f rm of acido i Thi i een clinically in certain cases of diab te in starvation occa i nally in hyperthyr idi m and in a variety of other di ea e state in which there is an ab lute or relative decrea e in carl ohydrate availal ility See THYROID GLAND DI ORDER

In keto i the breath has a fruity odor and there is u ually eviden e of del ydrati n weakne s malai e headache nau ea and vomiting are common Se DISEASE PATHOLOGY [F.C.T.]

Kidney

Pair l tructures fo ind in the d r al regi n f th l dy ca ity f animal l el nging t the rt l r te al phylum Tl e organ j rf rm a maj r part of the work f maintaining body fl u l at j r per concentratic n and comp iti n C mparati e study of kidney tructure re eal vari u a lapt ti n te l ted l i fly to th water pr llem in vari u l abitat and gge t th j ien f en ir nm nt f li we f in rtel rat e l iti n

The nephron Tl tru tural init fr m wl i h all ki fn y are f rmed i tl n phr n an e il l al t il ul mi r ji in i an l r wl i arall in tru t ire In a typical ex mpl (Fig 1) ll d from the renal art ry ja tl r ugl a l i t r of capillary l p tl e gl m r Bl l pr



Fg 1 D g m t sh w t t f ph ( ) E t ph on (b) R l p l ly d ct d t sh gl l

f es a p rt of th bl d ell a d l rg m lec les e pted t filte th gh th perm ble gl m rul wall nd t t th e p ded e d of th tubul Cell n th w ll of thi tub le xt ct f m th p g filt at th b t n e t d s tned f x t n d t rn them t th bl od adj ent p ll The e ell al xt ct cert n bst f m the blood d e c te th m int th tubul Th u e thu p od ced by e ch phron c n eyed by d t t th ts d u lly by way f bl dde

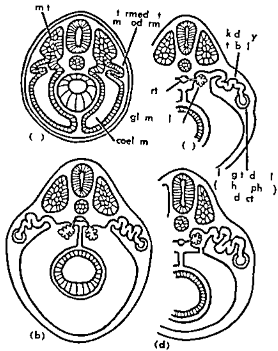
Evolutionary aspect It a um d th t the est rs f ert b te we e m r f rm with body fl d at m t c qu l br um w th ll gr t t f e h wat r pos d th th t of r p d l t n f b dy fl ds by o m Th phr b bly ev l ed d e wh h w ld u e bl d h gl m rul A l g gl m l p es nt mph b nd fi hes f d in f h w te t d y m th n est l typ H w whe fi h r ded th oc n ev l ed t l d f rms th ses n f gl m l bec m li b l ty b bl m w m t by d ff nt ad pt ti ev l es f es l t A f w t l t fi hes h l t gl m l ti ly d p od e by t b t n al Th gl m rul h b e re ed n th m fi he nd s m m y lt-e t g ll in tl g ll to f rth l

le te the w ter p oblem Sh rk retai the l rge gl mer lus b t ha e add d a pecial egm nt to the tub le wh ch retur urea to the blood i amount uffic ent t ra e the osm tic pre ure bo e th t of the cea Reptiles and birds ha e mall glom er li a d i ome ca es probably ave additio al wat by e c eti g nit og o s wa tes in the f m f a early d y p te f uric acid cry tals In the tubules of mammal and to a sl ght extent in bird a l ng thi walled intermediate s gm t has de el ped It i o effe ti e in water r o pti n that s me mammals i sp te of the r tent on f la ge glomer lu ar able t li e out their li es with ut acc t fre h water

Embryology Altho gh nephr ns are as embled to kid ey i a r ty f way the tubules l ways i i the intermed te mesoderm along the pp b rd r f th body ca ity (Fig 2) The fir t t bule dev lop at th a ter r end f thi me o- derm f llowed by ther in seque ce behi d Va ia tio s th s pla p m t the follow ng k d ey type to b d tingui hed

H l ph s Th r is one ephr n beside each m te long the nt e le gth f th co l m Sup- po edly th s s th n e tral c ndit o a d i thu efe r d to s n a ch neph o It ee today o ly in th l rv e f a few pr m ti e fi hes th myx d ycl tomes

P o ph s Neph s are formed only i the ter or pa t of the termediate me ode m The p o eph s s r ly f u d a dult xcret ry g n b t s imp rta t beca s in ll mbry s it it ates th f rm ti n of the a chi phr c d ct sed by b q ent t bul s fo dr i age The p o-



Fg 2 D g mm t ct f mbry t h w g f ph ( ) E ly t g with m d m d f f t t (b-d) L t t g

til, in some in t ces th y a sume a stag horn shape. Cal uli are somet mes harmle s and silent b t m e often c se some d fficulty They may lead t infectio by erod ng thro gh the pr t ti e epi thel m d pr viding a f thold for ba teria o by c ing ob truction to urine flow When a st ne pa int the u eter the spa m of the ureteral m scl in ts eff rts to xpel the to e cau a o- lent pa kn n a enal c l c This i ften a com pa ed by bloody uri e as the t ne te s m ll blood es ls Most c lculi are pa s d o t of the bod ia the et bl dd and ureth a Those h ch ar n t p ed may eq i e rgi l tre t ment lest th ob tructi and i fe t on pe man ntly dam ge the k d y

Infect ons Mo t i fect n f the kid ey are b c t n l a d el ted t the p l i Cla if tion c cord g to degr of er ty i as follow pyelit h n o ly the pel i lin s ol d pyel e- phr ti when the k d y ub ta e i als aff cted and p eph o i wh the pel i greatly dil ted d filled ith p Th e fectio s e h ra ter t ca'ly a sociated with s me form of obstr cti n h h h s au d st of ine a d a fa orable m l e f r b ct rial gr wth Comm n u of ob- l ct n a e co ge it l ab mal t e of th ur t rs n women p o t t c g wth in eld rly men d lculi, t mors r l f prop r erv ont l of bl dde mpty g f ll wi g pi l co d d es e n th Th rg m mo t f tm in l ed the l ba ll s and r lated gram negat e rod Th y p bably g i cce s t th k d ey by th bl od tream m e ften tha by a nd g th r t A t py l nephr t i a mp ed by h ll fev nd pu in th u ne Rec ry f m ingle attack i the rule w th h al g by rr g R peat d tta k chr i fe t ma destr y much k dn y t ss e th t ren l f l r u

T th l rms (fect on ar imp rt nt al th gh le comm Co t al b es es cu n p t t th t phylococcu pt c m s ngle mo oft n m ltuple l s If u h ab ruptu es t th t de through the p i le of th k d ey pe n ph absces i f rmed Tube u k o g m may nte th k d ey by the bl d lymph f m p mary s t i th lu g th infected o gan I unt e ted a the k d ey may be dest yed b the tube l us proc s and it may also be pr d i the bl dder nd th k d y

Glomerulonephritis Th is p fi f rm l renal nfl mmat p rt c l ly ol g the glo- m rul Appare tly it result of a r ti n be- tween ulat g t ept coccal t n and t bod es p ese t th c ll f the glome l The b cteri h b them el e do t i r the k d n ys f nd h efly th thr at Th e a e two m n t (th d a Type I h abrupt et, ll) 2 weeks ft r n acut st ptococc l inf ct n Th u s m ky blood the blood p es u e h gh and n t g s blood, M t pat nt rec e mpl t ly lth gh a few die in the early stages and a few others de velop hron c nephr t s Type II cases ha e an in s d ous n et with no ob i us preceding infection They manife t edema of the legs and eyelids ane mia protein uria and later hypertension Com plete reco y is ra e and there is usually gradu l p gr sion to omplete kidney failu e o er a pe riod of e e l ar In the early stage th k d n ys are e l rged l ter becoming increa ingly s arred and shrunken The glomer lar tuft are fir t enla ged and c llul with lat r carr ng and final di appearan e The rine c ntain red bl d cells and d ol ed protei which leak th gh the dam aged glome ul a well a precipitated pr te n n th form f ca t f the t ib le

Nephrosis (lipoid nephrosis) This is a disease of m ll childr n At the o et the e is a g adual c um lat on of t s e fl d noticed first as swell ing of the eyel ds and legs Th re is a marked lo s f protein in the uri e Th re ulta t ery l w level of serum album n is nadequate to perform th n r mal o mot c function of pull ng *wat r from the* t ue spa e nt the bl od tr am h nce the edema The blood ch le te ol i es to a very high level po sibly as th r s lt of the body s *tt mpt* to compen te f th l we ed pr tein le el The r n l l si n are btle c ns st n hiefly f well ng of th walls of the glome ular c p ll i s These sw llen w ll ar ex i ly p rou and th pro- te s l k th o gh them The ca e of thi ailment nk own alth ugh m st ca e e pr bably form f gl m r lo ephrit s nd elated t st epto- co cal tox s Some f th h ld en m k ompl *te* e r Othe d e f m b cter l i fections t whi h they are tremely sceptibl o fr m in t f r with b dy f n t n aus d by e c s i ac mulati of fl d Oth r develop hron c gl merul phr t w th hyperten n hemat r a and re al f l re

Nephrosclerosis Thi t rm f eq e tly appl ed t kid y d maged by rte i l s s or arter l cler U d th e o d t n s the rt r al v el *ithe large o m ll bec m* progre s ely n owe th p t o f r al ub t ce whi h they s i ply a e grad ally damaged by a x d e tu lly d *to be* epl ed by s t ue The k d ey lowly h ink and the t r u f ce be ome ough ed by depre ed a which lter n t w th th hyp t phi d st ll h althy terve i g t s u Ult mat ly m h p e hym may be de t oy d th t e l fa lu (c rs N phr l ro- s s only p rt of g n r l d d rd r f arte es alth gh th re al l em t m y b th d m a t f at e In th mal gn t f rm f n phros le ros s, th *arter le b* com c t c and rupt g g a fle bitten appe n to the k dney r f c l th form f th d a the ry h gh blood p e a d d th o s ea *ly*

If d bet c mpl t n ph o l ro th r two d t nct e *feat e One* an ext me nar r w g f th t role the g n f the glo- m l The th r th p ese e of p cul r ound d p ts in th gl m rul Th i lled intr p l

nephros is of interest also because it shows features presumed to be primitive and suggesting a series of stages in evolution of the nephron as shown in Fig 2

Mesonephros The nephrons form behind the pronephros along the middle zone of the coelom The tubules usually become involved in sperm trans port Drainage is through the archinephric duct The mesonephros never forms an entire adult kidney It is functional in the chick and other amniote embryos

Opisthonephros Nephrons develop from the mid dle and posterior portions of intermediate meso derm The middle mesonephric tubules sometimes form only a minor part The archinephric duct may be supplemented or even replaced by ureter like accessory drainage ducts This is the func tional adult kidney in amphibians and fishes

Metanephros Nephrons form from only the ex treme posterior part of the intermediate meso derm and are drained by a distinctive new canal the ureter which grows forward from the base of the archinephric duct before the tubules have be gun to develop This is the kidney of adult rep tiles birds and mammals Their embryos show a distinct sequence of pro meso and metanephric kidneys (Fig 3)

Mature kidney The kidney as a whole tends to be long and straplike in fishes lying near the mid dorsal line and barely projecting into the coelom In other vertebrates it is considerably shortened

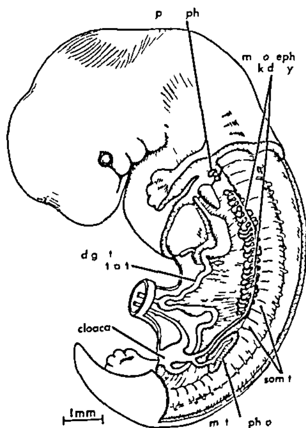


Fig 3 Human embryo of 6 weeks d sected to show the th ee success e k d eys wh ch d elop n th In termed te mesoderm

and extends prominently into the posterior region of the body cavity sometimes suspended by a mesentery The number of tubules in one kidney varies from one to several million depending in part upon body size but also upon metabolic rate

In all classes of vertebrates renal arteries deliver blood to the glomeruli and tubules Except in cy clostomes and mammals blood also enters the kid ney by way of a renal portal vein This carries blood from the tail and posterior parts of the body into sinuses surrounding the kidney tubules where it joins that brought by the renal artery and finally drains away through renal veins *See* URINARY SYSTEM [BBO]

Kidney disorders

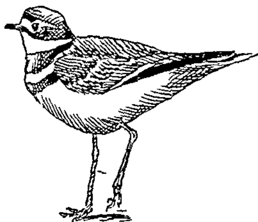
Probably because of their complex embryological derivation the genitourinary organs are frequently the site of developmental abnormalities Congenital absence of both kidneys permits only a brief po t natal life Absence of one kidney is common and produces no symptoms a single kidney being per fectly adequate for normal life Horseshoe kidney a descriptive term for fusion of the two kidneys at one pole is not rare Also familiar are double ure ters double pelves and aberrant arteries These conditions are significant only if they produce ob struction to the flow of urine Obstruction due to any cause leads to dilatation of the proximal struc tures known as hydroureter if the ureter is in volved or hydronephrosis if the kidney pelvis is af fected One characteristic form of maldevelopment is the polycystic kidney in which both kidneys be come greatly enlarged and converted into many thin walled cysts apparently because of a diffuse defect in development of the tubules Per ons so afflicted usually develop renal failure and die in middle adult life

Calculi Stones in the kidney pelvis occur fre quently There is a deposition of chemicals pre ent in urine apparently starting in the tips of the pa pillae later protruding into the renal pel is and ultimately breaking free There are several differ ent chemical types of calculi occurring under dif ferent circumstances Uric acid and urate calculi reflect excessive metabolic production of the e sub stances and appear particularly when the person suffers from gout Calcium oxalate calculi com monly occur if there are excessive oxalates in the diet derived particularly from fruits and vegeta bles Crystalline calcium carbonate and pho phate stones may occur when an overactive parathyroid gland increases the excretion of calcium when too much milk is ingested or when alkalo is decrea es the solubility of calcium salts Amorphous carbon ates and triple phosphates are characteristically found in calculi as a re ult of infection and sta : probably l eing deposited around a c re of pus and bacteria Small calculi may be compo ed of a sin gle component large calculi usually are of mixed composition

Stones may pass into the ureters when they are small or may remain in the pel and enlarge un

Killdeer

In f m r than 60 pecie f hor bi ds of the m! Char dr Iae char cter ed by bill wh ch s sh rter than the head cont a ted at the middle d lghtlv s lle te m ally The n ck i me- h t h te tha that of the andp per There re ght sp c es n th Unit d States cl di g the kllldeer *Ch d iu cife* the be t kn w of all N rth Amer ca h re b rd The Ameri an g lden pl *Plu l d m i s* is not worthy f rit u so l m g atio r ut Ther are two dis



Th k ldee Ch d f l gth 10½ (F m E L P I F ldb ok I N I l H story M G w H ll 1949)

tinct r s F ll m r nt f the e t m r e le e th A ct c t d h m nd fl m ly th sea, d rectly f om w E gl nd t the pla n f South Am rica They ret rn n the p ng l r ly f h n d e t r ly l d by w y f Cent l Am i Mex d th Gr t Pl n S CH RADRIIF RM [J D B]

Killifish

A y f a la g fam ly of fi h th Cyp no- d t d u ally with ft fi yel d ales d f small to m d t s e M t f th Amer n k ll fi h l a th su fa e of th wate ma y l th mar ll d t p m n w f th re son In rd w th th h bit the t p f the h d i flat tened nea the t th m th pens l g th uppe u fa e f the h ad a d th d r l fin t set fa b k Th k ll fi hes l y egg b t re the m l t th l ly l ted l be e u h th e ppy d *G mbus* S GUP Y



Th k llfish F d l p l gth t 4 l (F om E L P I F ldbook I N I I H st ry M G H ll 1949)

Many of the pe ie of this family e h l it harp exual dim pl sm tl e m les nd fem le l eing marked in di t ctly d fferent patterns Kill fi hes are widely d tr buted i No th a d South Americ Afr ca Sp i s uth n A ia and tl e Fa t In l es In the United States they are most comm n i Fl r ida There re l tl fr h wate a d marine pe e the latte f eq enting hallow brack h water Fresh wat pe ie oc ur in the hoal areas f lakes a d i t am S CYPRINIFOR IES SEXUAL DI IORPHISM [J D B]

Kiln

O e of e ral type of tructur f r heati g ce ram c (ea thy) m t ial in either their r w or m ld d fo m The heating p o e i all d firing wh h m y m n ither th oper ti n f th k ln r the tr tme t f the material in it bu n ng i a m e c lloqu l term appl d to the t eatme t of the prod t Wl en the he ti g s f unf rmed ma te ial t i ft alled calci ng

Ther d s t app r t be any le r cut d t t m e tl eryday u age r techn cal ter m nology b t e n th t m kiln f ce to e nd o e H we r a fairly widespread u ge n t e t ely co t e t r n t h c l te m K l seem t b ed ge erally n heati g f e amic mat r al t m th ng l th n mplete melt g f x mple eme t k l l me k ln b i k k ln and p tt ry k ln The term f ir a e i c mm ly ed wh n melt ng i i l ed i bla t furnace p he th f r ace nd gl s f r ac The l tt r may b alled a gla ta k wh the p c is c n t nu u but n a gla k l St e i u d t des- ig te a ga he t r su h s the hot t e ted w th bla t furn e In the c r mic du t i e are ge lly rel t ly low t mperatu e de- c s such a d y ng n n the ther h d the coke n i r lat ly high temp ratu e de ce S FUR ACE CONSTRUCTION CLASS AND GLASS PRO UCTS

Shaft kiln Th type of kil s u d f r al in i g op at n u h s h tin l mest e t f rm l m qui kl m Raw mate ial i f d nt the t p and m e d w th ugh h t ga s flowi g up f m b r n e the s de at the l ttom the l d p duct em g s fr m the b tt m *S e* L IE (I DU T IAL)

Rotary kiln Th type f k l s cyli d up t 4 0 ft l ng l ed with r fr t ry i l d at a l ght gle d r tat d at a l w peed (b t re l t per m ut) A bu n (the f l is u ally p wde ed c al l) i pl ed at th l wer e d d th h t ga m e to th uppe end Raw m te al i fed nt the upp r end sl wly tumble d n th l ngth f th t be a d d p out th l e e d Us ally t f lls nt a o le in wh h mb t p h t d Th m t mm n u f ot y k l i mak g p tl nd ment S e CE IENT

Th h ft nd t ry k l f tr t ng of rmed m t l p at c nt u ly Bat h ope ti f r w mat l e l c mm n but gyp m f

lary glomerulosclerosis and is associated with marked albuminuria

Kidneys in hypertension The kidneys are almost invariably diseased when high blood pressure is present but there is not a simple cause and effect relationship In the ordinary essential hypertension kidney tissue is often entirely normal after hypertension is well established strongly suggesting that the lesions of nephrosclerosis are the result rather than the cause of the elevated blood pressure Apparently the prolonged arteriolar spasm necessary to maintain the high blood pressure eventually leads to organic damage to arterioles followed by scarring of the kidneys On the other hand it is well established that damaged renal tissue may release pressor substances capable of causing hypertension Pressors may be produced in a kidney whose major arteries are markedly narrowed or in which pyelonephritis is present The hypertension so produced can be eliminated by removal of the diseased kidney

Lower nephron nephrosis This is the most widely used appellation for an extremely important acute reversible form of severe kidney shutdown It occurs following prolonged shock and hypotension or after absorption of certain hemoglobin compounds following incompatible blood transfusion or after destructive injuries of muscle The sequence of events following the original injury is suppression of urinary secretion usually complete followed by rising blood levels of nitrogenous wastes After about 10 days urine secretion usually commences again but the urine first produced consists chiefly of water with relatively little nitrogen In due time which may be as long as 2 months the renal function returns to normal Death is not common unless the original injury is itself fatal or the patient receives too much fluid which he cannot excrete Because of its reversibility this particular renal lesion is one of the best suited for treatment by the artificial kidney

The renal lesions are relatively subtle and inconstant consisting of edema of the tissues between the tubules heme casts in the tubules and focal injury to tubular epithelium chiefly of the distal nephron

Renal failure When the kidneys are unable to carry on their normal functions of excreting waste and balancing the internal chemical environment of the body renal failure is present This may occur abruptly as in lower nephron nephrosis or obstruction of the urinary tract but most often develops gradually because of progressive destruction of renal tissue by disease The sequence of events is about the same whether parenchymal destruction is the result of pyelonephritis glomerulonephritis nephrosclerosis or other cause

In the early or compensated stage the kidneys lose their functional reserve that is the ability to meet stress The power to excrete concentrated urine when little fluid is taken in or to excrete a dilute urine when much fluid is ingested gradually disappear and the urine specific gravity ultimately becomes fixed at 1 010 the specific gravity of an ultrafiltrate of blood serum Similarly nitrogenous wastes cannot be selectively concentrated but are merely washed through Also ability to excrete bases or acids to compensate for shifts in intake and to maintain the normal pH (7 4) of blood gradually vanishes

In the later or decompensated stage complete excretion of certain substances is no longer possible and their blood concentrations rise Most important of these substances are potassium phosphates and nitrogenous wastes such as urea and creatinine Sodium and water accumulate in the tissues in edema fluid Edema is also aggravated by fall in serum albumin caused both by loss in the urine and poor intake in the diet In children with chronic renal failure the phosphate retention produces severe disturbances of calcium metabolism which sometimes results in a bone disorder called renal rickets Anemia is usually present for several reasons of which probably the most important is destruction of red blood cells by circulating poisons

The end stage of renal failure is uremia Symptoms include convulsions vomiting diarrhea and coma Lesions are found in many organs They include fatty droplet accumulations in heart muscle acute fibrinous pericarditis ulcers of the intestinal tract a white powdery frost on the skin and edema of the brain These changes are reversible if the renal failure can be relieved Extensive studies have failed to pinpoint the particular poison or poisons responsible for the individual lesion

Cysts Single or multiple cysts with thin walls containing clear fluid are extremely common They often result from obstruction of tubules by scars and are not important except in polycystic kidney

Tumors There are three important malignant tumors of the kidney all having a high mortality rate Wilms tumor found in infants is made up of a mixture of small glands and of sarcoma cells particularly of muscle type it is often termed an adenosarcoma The tumor usually occurs as a large abdominal mass and is rapidly fatal if untreated Some children are cured by radiation and surgery Renal cell carcinoma or hypernephroma grows in the renal substance of adults as a hemorrhagic yellow usually encapsulated tumor The first symptoms may be irregular fever hematuria or those of distant metastasis Because it invades the veins early it tends to metastasize through the bloodstream particularly to lung brain and bone Metastases may appear many years after the kidney tumor has been removed Sometimes there may be solitary metastases curable by surgery Transitional cell carcinoma arises in the epithelium of the pelvis produces hematuria early and tends to spread down the epithelium of the ureter *See* KIDNEY METABOLIC DISORDERS ONCOLOGY URINARY SYSTEM [R N B]

Bibliography A C Allen *The Kidney Medical and Surgical Diseases* 1951

pro ectu n f fi e ware (a in decorat ng d nner ware) s needed the high co t of lectr c heating m be justified It is u ed widely in labo atory f aces bec e t p rmits cl e temperature control S e CERAMIC TECHNOLOGY PYROMETRIC CONE TEMPERATURE CONTROL, AUTOMATIC [M C M]

Kilogram

A nit of m s The ta dard of mas n both the mk and cgs y tems of units s a platinum rid ium cylind alled the t ndard k logram The un t of ma i the mks syst m is the ma s f the st dard kilogram The u it of ma in the cgs system $\frac{1}{1000}$ f th s ma s and is called a gram A kil gram weighs 2.20462 lb a d a metr c ton con t n 1000 kil grams

The kil gram s al o omet mes defined as un t of f rce that i the weight of a 1 kilogram m ss hence the xpre o kilogram f rc Se MASS UNITS SYSTEMS OF [L.N]

Kinematics

That b an h of m ha ic whi h deals with the mo ti n of a sy tem f mat l particle witho t refe en e to th for e wh ch a t n the sy tem K ne m i c d ffer f m dyn m cs in that the l tter takes these f e nto cc nt See DYNAMICS

Fo a l p rticle mo ing n a str ight line (rectil e r m ti) the motion i p esc ib d when the pos ti f the part le s k own a fu c ti n f the t me F r un f rmly acc le ated m ti n,

$$\frac{d^2x}{d_t} = a$$

h e t th c ta t eler t on and he ce

$$x = \frac{1}{2}at + v t + x_0$$

h x_0 d t e the n t al po tion and el city of the part l p t v ly Se ACCELERATION M TION RECTILI E R VELOCITY

Pl k em t of part l is c n er d with th pecifi t of the po ti of a pa t le m ing pl by m a s f two d pende t ari ables u ally th ect ng l r atte an c rdi ates x a d y b t ften th p lar coo d nat r = (+ y) θ = t (y/) other co r d ates that m y be espec lly o en ent for p rt la p blem Her the x a d y mp ent f loc ty e d /dt dy/dt nd f c lerat on d² /dt d²y/dt espect ly but th c mp ent of loc ty the d ect n of n e i g and i er g θ r d /dt a d (dθ/dt) and are th not so mpl g i t ms of th t me d i ati es (th oo d n te

The k nem t s l p t le i sp on med w th th w y t wh h thr depend t oo d tes may be ch en to p fy th p ti n f th p rt l t gi t m d w th th el tion bet ee th fi t d se o d tim der ti f these oord tes d the mpo t of loc ty a d a l t n of the p rt le Th m t n i per fied f th ee ch oordinates are g n a

functions of the time and the path of the particl in pace s then obtained by eliminating the time b tween thes eq iation

For de cr bing the simultaneous position in space of N particles 3N c o dinate re necessary and the configu ation of the system may be repre s nted by a point n a 3N dimensional pace called th configuration pace of the system As the parti cles mo e the corr pond ng representati e point in configu at on pace traces out a curve called the trajectory of the ystem If the particles do not move independ ntly but a e ubject to m con straints that i if m rel ti ns between the $3N$ co-ord nat s cont nue to hold throughout th m tion then it is possible to represent the trajectory in a space of $f = (3N - m)$ dime s ns f being the n mber of degre s of fr edom of the ystem See CONSTRAINT DEGREE OF FREEDO (MECHANICS) For a igid body e en though N and m a e ery large $f = 6$ and the c nfigu at on at any time may b represented by i ndependent variables (usu ally three t r pr sent the pos ti n of the c nt r of ma and th e angles to pecify the o ientati n of the body ee CAYLEY KLEIN PARAMETERS EULER ANGLES) Ki emat s de cribes the rel tion be tween the t me der tives of such angl s and the omponent f the ng lar eloc ty of the b dy

Amo g the coo dinate sy tems i died in kine matic a e those u d by ob ervers who are in rel i e m tion In nonrelat i i c kinemat cs the time o d ate fo e ch such bserver is ass med to be the me wh r s in relati tic kinemati s pr pe a co nt must be tak n of the fact that length and time nterv l app ar d ffe nt t ob rv rs mo ng relati e to ach other S e RELATIVE MOTION [H C C]

Kinescope

A cathod ay tube used as tele s on picture tub It m ght al o b refe ed t a a telev i n p i e rep odu r Modern televis n p cture t bes u u lly ha e l g gla e v l pes (se F g 1) on the nner fa e of wh ch a l ght m tti g layer f l m n c nt mat i ls i d p t d A modu lat d t m of high l ity electr s is made to c th s layer n a s r f ho iz ntal lines s that t ecreate the p tur element (light nd dark s a)

The numb r of le tr ns in th t e m at any in t t of t me is va ed by ele t i l mp l es o pond ng to th gn l ent o t by the televi o tr n m tter Th le tr cal imp l s (p t ire nfor m t) ent ut by the transm tter w e origin lly g nerated by a tud televisi n am ra The l m televi n e i p cks p th s gn l nd aft r u tabl ampl fi at o nd detect on the pi t r nf rmat n s uppl ed to th picture t b so that it will r cre t the g nal pi tu e Se TELE VISION

Construction Th mo t p p l pictur tubes rrently in u e re the 17 l a d 23 i t gu l z Th d m n i n ref t th d agon l of th e ta g l r fa e Fo d t iled d

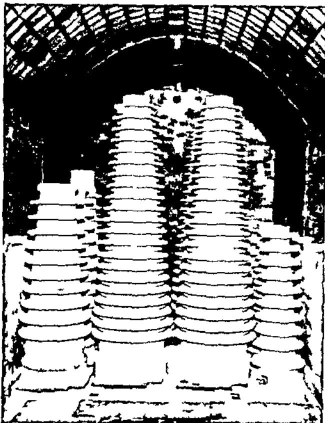
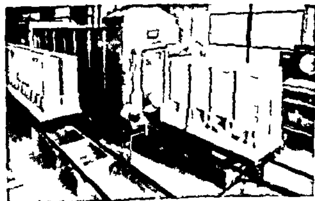


Fig 1 Interior v ew of a period c k ln show ng a set ting of electrical porcelain insulators ready for f r ng (Swi dell Dressler Inc)

example is heated at relatively low temperatures in kettles to form plaster of paris *See* PLASTER OF PARIS Kilns for firing formed ceramic products may be either periodic or continuous in operation

Periodic kilns In this type of kiln the cycle of setting ware in the kiln heating up soaking or holding at peak temperature for some time cooling and removing or drawing the ware is repeated for each batch Such kilns range in size from labora tory or art pottery kilns with chambers a few inches on a side to large domed structures 40–50 ft in diameter used to fire l rick and other heavy clay ware Large combustion fired kilns are known as up or downdraft kilns depending on how the hot gases mo e through the kiln from f rebox to ex



Fg 2 V ew of a m d um s zed tun el k l d to f e t fed ce am c floo t le (Sw dell Dress l I c)

haust Periodic kilns have relatively low efficiency because the heat used to raise the kiln it elf to temperature is largely thrown away each time the kiln is cooled although some of the heat may be used to operate a drier

Chamber kilns This type of kiln repre ents the first step toward continuous firing and it con ts of a series of adjacent chambers in a ring or o al Firing is arranged (with a movable stack) so that the fire moves from chamber to chamber around the ring taking several days to make a com plete circuit The flues are so arranged that wa te gas from the fire passe through chambers toward which the fire is moving and heats them while the combustion air is lead to the fire through chambers already fired and is preheated The preheating of both ware and combustion air (by wa te ga es and cooling ware respectively) gives a considerable in crease in efficiency over the period kiln Although widely used in Europe this type of kiln was never adopted in this country

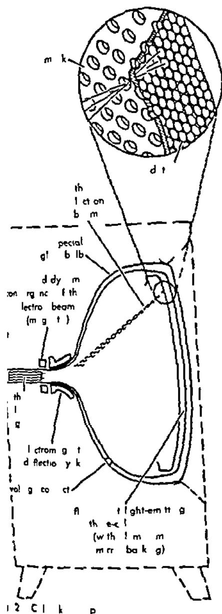
Tunnel kilns These are long structures with the fire located near the midpoint The kiln is de signed so the temperature rises gradually from each end to a maximum in the middle Ware is fired by loading it on cars which are pu hed through the kiln thereby subjecting the ware to a heating soaking and cooling cycle Since the kiln it elf re mains at essentially the same temperature and only the ware and kiln cars are heated and cooled during each cycle operating efficiency is higher both in terms of fuel savings and of less wear and tear on the kiln Tunnel kilns range in size from a few feet long (with a cross section a few inches on a side) to over 100 ft long (and a cross section up to 6×8 ft)

Muffle kiln In this type of kiln a refractory wall or chamber prevents direct contact between the flame and the ware It may be periodic or con tinuous in operation and it is used in firing prod ucts such as high grade dinnerware when the price of the ware justifies the expense of a le s efficient firing operation

Kiln furniture These are refractory shapes used for setting and supporting ware in the kiln They include pins on which glazed ware is et and the posts and plates from which shelves are built on a kiln car

Saggers a type of kiln furniture are refract ry chaml ers or l oxes in which fine ware i et for fir ing They differ from muffle which are a structural part of th kiln in that they are et in the kiln at each firing Be ides protecting ware they provide support for piece which l ecome soft at the firing temperature

Heating Heat f r kilns may be ol tained fr m the coml u tion of wood (largely ol lete) coal (becoming le s c mmon) oil or ga or from elec tric heating element Oil and ga are preferred f r large manufacturing operati n l ecau e they com l ine economy with fair ea e of t mp rature c ntrol When cl e temp rature contr l of a high priced product (f r example electroceramics) or when



2 C l k p

Color kinescope A c l r t l i p tu tub m l t th bl k d white p tur t ibe but ff in t way (1) Th light m tt ng e m d p f m ll elem t l e h p l le l m tt g l ght n e f the three p m v l (ed g bl) l d t nt l ed r y (2) M a p d d f le t ly t g an m f th ph ph p m e C l m y be t ll d b a y f th ee meth d (1) se g h h t urat lect n beam ting l des ed ph ph r a w th feedl k g l f m th n th gh r tr wh h m r t t j t g f th l m( ) (a t h g d d g t red w th th n b h d fl t th l am t the pr per th th (3) a sc ee t u t e wh h p de f mph t tat d g t n d t l eam d ection g lly ed w th th e gul rly sp ced be ms The third devic i termed a shadow mask tube

All c lor pictur ti be are omewhat limit d in l ght tput as mpar d w th l l ck and white ti bes by the f ct that th ph pho s are h en for ex ell nce of primary col r rathe than high lumi us efficie y S me c lor systems have add ti nal output lim tatio f the e re n col r tubes are usually operated at higher c rrents a d v ltage than their l lack and white c unte part Altho gh each colo tub vstem has certa n ad a tage only the shad w ma k type ha be n c f lly devel ped for high produ tio Its ad va tages are it abil ty t pr duce c lor as pure a it ph sph r p im ie it ex ellent co t a t th fea bility of u g it i a fine barely percepti bl d t s een t ct re and the fa t that the cur re t fr m three beam a il l e f r imultaneous p e e tat n A cu re tly a ailable c mme cial h d w ma k tube con t of a 21 n-diameter r nd gl b lb 70 m x mum d flecti n angle a triple b am gun having elect ost ti l cu nd m gn tic me n fo keep ng the three ele tr n b m c nve ged to a p nt and a urved ap rtu e m k reg ter d with and l e to the pho phor d t ee The d t in he gonal r y dep ted on the sph r cal faceplate M gn tic sca ning a d yn h nized dynam c on ergenc are u ed (see Fig 2) S e COLOR TELEVISION [C I S]

B bl g aphy L S All rd D ign f ctor n t le n th d ray tub s *P oc IEE (Lo do)* 99(3a) 499-507 1952 D C F nk (ed) *T le s n E g n i g H ndbo k* 1957 H B Law A th e gun shadow ma k ol r k e cop *P oc IRE* 39(10) 1186-1194 1951 H R S ele et al D el pment of a 21 m tal e vel pe c l r ki e sc pe *RCA R t* 16(1) 122 139 1955 C P Sm th t l De gn nd d l pment of th RCA 21CYP22 21 i ch gl l p tur t be *RCA Rev* 19 334-348 1958

Kinesthetic sensation

Th k d f feel ng gin ti g i bod ly mo ment d ar g fr m tim lat n of th n o y erve that t m n t n mu le te d n d j nt It i by m f k ne th (l t lly f l ng f mo- t) th t t l e m p ble t w lk w th it look i g t the f et eat with ut w t h g th hand con ey food t th m th r t mate th w ght of ob- j t me ely l y heft ng th m

F r well o e c t ry e the t me f S Ch les B ll (o d 18 6) the m cl e a t wa th lled h been rec gni ed a s xth t b dd d t th cla l f e of Ar t tl g he ng feel g m ll a d t t At fir t ry et n l m m les w tl ght t l lu ly esp ble f pply g f mat n abo t po t al h g H w e th ev de g ad ally c me to fa tl nerve e d g t te d d ti l (jo t) t p di g th b lk f ch d t Now t i kn wn th t app ta t of limb m m nt he f the maj ity f post r l dj tm t n y d by w y f re ep-

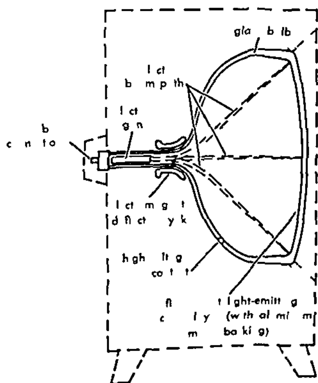
cathode ray tube construction *see* CATHODE RAY TUBE This article discusses construction specific to kinescopes

Deflection angle This is the maximum angle through which the electron beam must be deflected to scan the picture area Most tubes in use today have deflection angles of 90 or 110

Focus Picture tubes are defined by the method used to focus the stream of electrons to a small spot There are two general methods magnetic fo cus using a strong external electromagnet and electrostatic focus accomplished by applying voltage differences to the electron gun electrodes Electrostatic focus has become universal because of its lower cost

Electromagnetic deflection The electron beam is deflected electromagnetically to cause it to scan the picture area Thi deflection is accomplished by a deflecting yoke made up of two pairs of shaped coils which fit around the small neck of the picture tube (see Fig 1) When pul ating electric currents of proper wave shape and phase are supplied to these coils they generate magnetic fields which cause the electron beam to bend as it passes through them By changing the magnitude and di rection of the magnetic field the electron beam can be made to arrive at any point on the face of the picture tube

Glass envelope The glass envelope is made of a pecial composition to minimize optical defects and to provide electrical insulation for high volt age It also provides protection against x radiation and has a light ab orption characteri tic which im proves the contra t of the picture when it is viewed in brightly illuminated locations The structural de ign of the glass bulb is made to withstand



Fg 1 Black-a d wh t k n scope

3–6 times the force of atmo pheric pre ure to provide a safety margin over normal atmo pheric pressure However care must be taken in handling these evacuated gla s bulbs or a dangerous implosion may result

Alumini ed screen The lumine cent creen is made of a thin layer of phosphors 0 001 in thick (3 mg/cm²) The phosphor materials are primaril zinc cadmium sulfide (emits yellow light) and zinc sulfide (emits blue light) By careful proporti n ing and mixing of the e two phosphor the result ant emanation is a blue white light which most manufacturers have adjusted to a color tempera ture of between 9000 and 12 000 K

The lumine cent screen is aluminized by vacuum evaporation from a small molten aluminum pellet The thin layer of aluminum approximately 2000 Å is deposited on a smooth plastic film placed on t p of the lumine cent screen The pla tic film is ub sequently volatilized and removed in the high tem perature proce ing of the tube In the operati n of the completed tube the high velocity electron beam *penetrates the aluminum* film and it energy is transferred primarily to the lumine cent creen Only a small percentage (10-20%) of the elec tron beam energy i converted into u eful light en ergy but even this amount is sufficient to produce brightne s of everal hundred foot laml erts in the picture highlights The reflection of light by the aluminum mirror increa e the picture brightne and improve picture contrast by preventing tray light from illuminating the back ide of the lumi nescent screen

Wall coating Graphite coating are placed on the inside walls of the bulb to provide electrically conducting surfaces between the creen and the electron gun and to provide a unipotential field through which the electron l eam may travel ith out being disturl ed l y tray ele tro tatic fields Graphite i a sufficiently poor conductor to mini mize eddy current power al orption from tl e elec tromagnetic fields generated l y the external de flecting yoke

Electron gun The electron gun prodi ce a stream of high velocity electrons which are f cused to a small spot at the screen In currently u ed commercial tube the spot produced l y the electron l eam at the screen i apj r ximately 0 025 0 125 in in diameter dej ending on beam current required (u ually 50–1000 micr amperes) The l eam current is controlled l y an electrical ignal supj lied t the catl ode with re pect to grid No 1 called catl de dri e or t grid No 1 with re pect to the cathode called grid drive Con en tional tul requ ire 50 125 lts c f ignal to modu late the l am fr m zer l eam current (picture dark ar) to maximum l eam current (picture high light)

Tra i torize l portal le l attery oj erate l Tl re cei ers i picture tul e requiring le signal volt ag much le s p wer for deflecti n of the electron l eam and smaller amounts of power t l eat th cathode from wl ich tl e electr n are emitted

d tributi n f nction The main purpo e of ki etic theory is to deduc f om the t ti t cal d cr p- t n r lts al d fo th wh le sy tem The d s tinct bet een kinet c theory nd stati tical mechan es is th f nec ty arbitrary and ague H t rically k eti the ry s the olde t stat sti al d scipl n Today a k n tic c lculat on refers t any calculat o i wh ch p obabil ty methods mod els, r d trib t on funct o s are n olved

F r inf rmat n hi h is relat d to and upple m ts the pre ent rt cle *see* STATISTICAL MECHAN ICS *s e al o* BOLTZMA N STATISTICS BOLTZ MA N TRA SPORT EQUATION QUANTU I STATISTICS

Classes of problems Kinet calc l t on ar n t rest ted t ga es but o c r n chem cal p ob- l m sol d stat problems and pr blems in r d a t n theory E en tho gh tl g neral pr edure i th se d ff rent areas are im la there a e a uffi c nt n mber f impo ta t d ff renc s to make a gen l la ficat u ef l

Classical d al equ l bri m p obl ms In the e there a e o i t a t on between the n titu nt of th s tem Th sy tem is qu l b m and the mech ical l g ern ng th sy tem re cla al The b inf m t on is co ta ned n the Bo ltzma n d tribut f (al call d Ma well r M x ll B ltzm nn d tr buti) wh h g e the n b of parti le i g e momentum and po ti l ge ($d\,x = d\,d$)$d\ d\ = d\iota\ d\ d$ wh e x, y and a e oo d nate f po t o a d t t a d e coo di tes of l city)

$$f(xy \quad \iota \quad) = A\,e^{-} \tag{1}$$

H i th ene gy nd $\beta = 1/kT$ (wh e k i th B ltzma n t t nd T s th absol te tem per tu) and A a o ta t dete m ed f m (2)

$$\iint d^3\, d^3\, f = \aleph \quad \text{total n mbe f pa t cles} \tag{2}$$

Th e lcul t f gas pre e p ifi heat nd th l cal equ p rt ti n theorem e all ba ed n th se r l t n

Cl al id l qu l bri m p bl m Ma y mporta t phy al p ope t e refe t t q l b m b t t n q il l um tates Th me a h th m l c d t ty ty and elec t ic l cond t ty ll r qu e a d c on tart g f m th B ltzm n t po t q atio

$$\frac{\partial f}{\partial t} + \quad \nabla f + \aleph\,\nabla f = \left(\frac{\partial f}{\partial t}\right)_{coll} \tag{3}$$

I $\aleph$ = f r e pe n t m = ha g n f d t ll If o e d al w th t te that e ed n t be sol d b it t ffi nt t de be pe imposed a eq l brium t te E th gh ese d ffi lt app al t mple phy al p ct e f eq ntl l d t qu t t t bl express n term f th qu l b m d t ib t f ti Of ne l import the mpl of th o-called

electron gas in a m tal The k netic treatme t f th s sy tem f rms the basis f r th cla cal (Lorentz) conduct ity theory For tates far from equilibr um n g neral simple theory exi ts

Classical n n deal eqi ilibr um theory The ba c cla ical procedu e for arbit ary systems (sy tems with i teraction taken i t account) that allows the calculation of macroscop c entitie i that using the pa tit on functio

$$Z_1 = \quad e^{-\psi/kT}$$
$$= \frac{1}{\lambda^{3N}} \int \quad \int d^3x_1 \qquad d^3x_N\, e^{-(1/kT)U(x_1 \quad)} \tag{3a}$$

where $\lambda = h/\sqrt{2\pi mkT}$ Here ψ is the thermody nam c fre ene gy and h is Pl nck s con tant Al th ugh Eq (3) is written th t it may b applied to ga es th part ti n funct on may al be written for cl s al sp n y t ms s ch as ferrom gn ti lid parama netic ol d nd the l ke Th math emati al problems f e luat ng the ntegral or the um are d ffi lt. Equat n (3*a*) with appro- p iat m d ficati n is the st rt g poi t f r all these o id rat ns

Clas cal nonid l o equ l b ium the y Th is the mo t g ne al tu t on that cla al *tatis- t c* e n d cribe In g ner l ve y little is k wn bo t h syst ms Th Li u ille equ t on ap- pl s and ha be n u ed s a tarti g point for thes tud b t n p cta lar r sults ha e yet be n obtained F r tudie f th liqu d tate how er the results h e b n q te pr m sing

Q t m p obl m The e ar quantum c nter p t to the clas ificati n ju t d scribed I a qu ntum t atm t a d tr b t o fu t n s al u d f an ideal y tem n equ l br um to desc ibe t g n al pr pertie F yst ms of part cles hi h mu t b d cr bed by symmetri l wa e f tion s h as hel um at ms a d phot ns one h s

$$f(\quad \iota \quad) = \frac{1}{(1/A)e^{\beta} - 1} \tag{4}$$

wh e th Bo e d str but $\beta = 1/kT$ nd A is de t rmin d by Eq ( ) S BOSE EINSTEIN STATISTICS

F y tem of pa t cl wh h mu t b de crib d by a t symm tric l w f n t s h as el c tr pr to s a d n ut o h

$$f(\quad \iota\,) = \frac{1}{(1/A)e^{\beta} + 1} \tag{5}$$

U f the f n t n n l l ti n s ctu lly n t y d ff nt f m th e of th clas cal d t but o f ct o b t the res lt ar quite d f fe ent, a the a alyt l d ta ls As n th l s st te can b ed c d to a tr tment n ol g the eq l br um d t b t n nly The appli at to le trons as (ideal) F m D ra ga in met l th ba of th Somm rf ld theory f metal (s e FREE ELECTRON THEORY OF METALS)

tors at or near bony articulations The most crucial evidence comes from abnormalities Joint sensibility may be retained in the presence of muscular and cutaneous anesthesia of the same region The converse also occurs such as retention of sensibility of skin and muscle but failure to discriminate passive movement of the limb because articular sensitivity has been impaired

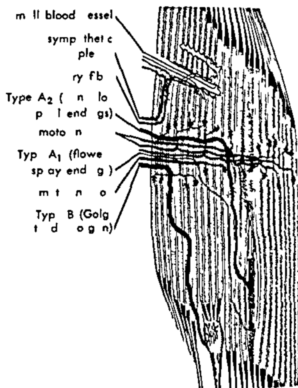
Kinesthetic receptors Four types of ensory nerve ending are involved in the appreciation of bodily movement They are (1) free nerve endings (2) Pacinian corpuscles (3) Golgi tendon organs and (4) muscle spindles

Free endings These are the most commonly occurring sensory nerve terminations in the body They are found in deep tissues—subcutaneous layers fascia (musclesheath) periosteum (bonecovering)—as well as at the cutaneous level where their distribution is almost ubiquitous and where endings of neighboring nerve fibers overlap and interdigitate with one another in some profusion The presumption is that it is the free endings of the periosteum and the fascia that contribute so heavily to kinesthetic sensation though this is by no means firmly established Free nerve endings are also suspect as initiators of pain which can be most exquisite in the periosteal and fascial regions

Pacinian corpuscles Pacinian corpuscles are the largest of the specialized sensory nerve endings in the body being situated suitably to serve as kinesthetic receptors They are found in the sheaths covering muscles and tendons and are scattered through deep fatty tissue Relatively few in number they are encapsulated consisting of many concentric layers of fibrous tissue containing nerve endings are attached to large diameter sensory fibers and are known to respond to any nearby distorting force whether it be muscular contraction or mechanical deformation transmitted from the body surface

Golgi tendon organs These organs situated near the junction of muscle fibers and tendon would seem to be most advantageously placed to report on muscle movement Recordings of electrical changes in th ir attached fibers show them to signal both muscle stretch and active contraction Impulse frequency has been found to be roughly proportional to the common logarithm of the tension impo ed on the tendon Golgi organs may therefore be thought of as muscle tension recorders

Muscle spindles The most complexly organized of the kinesthetic receptors are the muscle spindles which have two distinctly different kinds of terminations These ha e been de ignated Type A_1 (flowerspray endings) and Type A_2 (annulo piral endings) by the British phy iologist B H C Matthews who originally described them Typically A_1 fibers are of smaller diameter and are therefore slower conducting than A_2 fibers Both types initiate impulses when their mu cle bundle is tretched and generally cease firing impulses when the mu cle contracts The fibers leading from mu cle spindle therefore have been termed stretch afferents Type



Nerve e d gs in muscle sensat on (J F Fulto Phy ology of the Nervo s System 2d ed Oxf rd 1943)

A_2 additionally generates kinesthetic impul es when its muscle is very strongly contracted

Kinesthetic discriminations Since it is the receptors situated in the neighborhood of bony articulations that supply the most exact information about bodily movement the finest kine thetic di criminations are as ociated with joint di placements Measurement of the ability to di criminate such movements is accomplished by arranging for a limb or appendage to be moved mechanically and passively at a uniform rate and the least detectable amount of movement based solely on feel is determined In such experiments it is typically found that the greatest sensitivity is associated with the larger joints (hip and shoulder) while the les t is found in the ankle and toes At a speed of di placement of 10 /min thresholds vary roughly between 0 2 (hip) and 0 7 (main joint of big toe)

Since appreciation of postural change seems to depend mainly on articular sensitivity the roles of muscles and tendons must be secondary in kine thesis Muscular and tendinous sensitivities pre um ably add feelings of strain when resistance to limb mo ement is encountered as in lifting weight or pushing against stationary objects *See* SOMESTHESIS

[F A C]

Kinetic theory of matter

A theory which states that the particles of matter in all states of aggregation are in vigorous motion In computation involving kinetic theory the methods of statistical mechanics are applied to specific phy ical system The atomistic or molecular structure of the system invol ed is a sumed and the system i then de cribed in terms of appropria e

Equip t t n th rem and sp c fic he t In a cl l id l ga the erag ki t ene gy s soci ted w th y tr latio al deg e of f eed m the same

$$\tfrac{1}{2} \overline{\quad} = \tfrac{1}{2} m \overline{\quad} = \tfrac{1}{2} m \overline{\quad} = \frac{1}{2\beta} = \tfrac{1}{2} kT \quad (15)$$

It q t t a htf rw rd to h w that the ge energy a soc ted w th ny degr e f f dom h h occur as a qu drat c t rm the expres fo the me han c l e rgy i gi en by ½ kT For m ll the ult p es s th t f Boltzmann d trib t wr tte in term of m menta and g er lized oord t p d q h

$$\overline{q \frac{\partial}{\partial q}} = \overline{p \frac{\partial \epsilon}{\partial p}} = kT \quad (16)$$

h h i lled th q partit theorem F m th eq p rt t theo em th p fi he t C de- fi ed by

$$C = \frac{\partial \bar{E}}{\partial T} \quad (17)$$

m y be mmed t ly bt ned

If h j t th three t an l t al d g f f eed m the a ge ergy p degree f f d m pe m lec l ½ kT h nc th a ge gy $\bar{E}$ ³⁄₂ NkT a d C = ³⁄₂ R Th p ific heat i th t t d dep de t f T In th of d t m m l l n s lly h three t l i l d t t o l d gr s of f e d m The f $\bar{E}$ = ⁵⁄₂ NkT a d C = ⁵⁄₂ Nk ≡ ⁵⁄₂ R ppose th re a toms l d e ch b d b el t f e t nt l th t ca th m h l ergy w ll be

$$\frac{1}{2m}(p \;+ p \;+ p^2) + \frac{1}{2}k \;(x^2 + y^2 + z^2) \quad (18)$$

h e k i the el t c fo ce t t Ac d t th eq p t t th o m th t rm ll g e a p c fi h t $C = 3 Nk$ the D l g d Pet i l f m t m c l d (S ECIFIC HE T OF OLIDS) Th q p rt t th r m per ll ful whe g i t a t mper t h gh th i t b m ne e y t e elat t mech t d cr b th y t m p p ly Th h ppe at t mpe t f wh h th th rm l en gy kT f th m d m The p- r pri t r l i bet e n gy d m m t m then

$$= C[(p \;+ p \;+ p^2) + m c^2] \quad (19)$$

(REL TIVI TIC M CHAN CS) Th q p rt t latio (16) m th be tte

$$\overline{c^2 p^2} = kT \quad (19\ )$$

F m th t l t t t ect t th a th lt th l g gy f g

$$\bar{E} = \tfrac{3}{2} NkT \left(1 + \frac{5}{4}\frac{kT}{m} + \qquad \right) \quad (19b)$$

El ctric l c d t ity of m t l Exper men tally o e b erve p p rtionality between the appl d electric field a d the current p oduced in a met ll c co d t r Kinetic procedures g e an expl t of th general nnect on C de th l tr s in a metal as an ideal gas of electro of m m charge e In equilib ium the electrons a e de cribed by the B ltzmann d tr bution (1) or the F m Di c d t ib t on (5) C ll this distri b t f Be a f depe d n t + t + t o ly t clear that $\bar{t} = 0$ n et cu rent can fl w n eq l b m t te The applicati n f n ele tric field th r f re lt in the destruct on f th ph cal symmetry i the l t es Thi ffe t is d rib d by the Boltzmann tran p t equati n

$$\frac{\partial f}{\partial t} + \quad \nabla f + \quad \nabla f = \left(\frac{\partial f}{\partial t}\right)_{coll} \quad (20)$$

The llision te m cau es c derable d ffic lty In m y p blem o e j tified i trod cing r l t n time whi h may d pend n x d t d wh h defined by

$$\left(\frac{\partial f}{\partial t}\right)_{coll} = -\frac{f - f_0}{\quad} \quad (21)$$

H f s the d tr b t f n t at therm l equ l b m The intr d tio f su h relaxat t me p e upp e th t a o quil b m tate w ll decay e p ti lly t quil b um tate as on e q of the a t n f the ll io Th s s u d btedly a g od pp imat n r equil bri m A me th exi t e of n l tr fi ld n the d t n wh h d to t th n t l d t ibution a m ll m t By i g Eq (21) Eq (20) may be wr tten

$$\frac{eE}{m}\frac{\partial f}{\partial} + \quad \frac{\partial f}{\partial x} = -\frac{f - f_0}{\quad} \quad (2_)$$

H E s the t l elect c field If it s n w a um d that $(f - f\ )/f << 1$ with f very n r q l b m t t s th t q d t c te m m y b l cted a d th t the pa mete A d β n f dep de t f x the e plicit e p ss n f f be bta ed

$$f = f \;- \quad E_x \frac{\partial f_0}{\partial} \quad (23)$$

Th el tri c r t n th x d e ti n i lw ys g e by

$$J = \int e\iota\, f d^3 \;= -\; e^2 E \int \quad \frac{\partial f}{\partial \epsilon} d^3 \quad (24)$$

(Th fi t te m Eq (23) d not o tribut t th t h s l eady bee p t d t) Th n e mpl f a f rmal res lt in t p rt th ry The res lt f r J i n a form n wh ch ly k owl dg f the eq l b m d t b t r q d t bt e pl t we

In quantum theory nonideal systems in equilibrium are described in terms of the quantum partition function

$$Z_g = \sum g_n e^{-E_n/kT} = e^{-\psi/kT} \quad (6)$$

Here E_n indicates the energy levels of the system and g_n indicates the weights of these levels. If one defines a Slater sum by

$$S(x_1 \ldots x_N) = \sum e^{-E_n/kT}|U_n(x_1 \ldots x_N)|^2 \quad (7)$$

where $U_n(x_1 \ldots x_N)$ is the wave function of the state n, Z_g may be written as an integral similar to Z

$$Z_g = \int \cdots \int d^3x_1 \cdots d^3x_N\, S(x_1 \ldots x_N) \quad (8)$$

For the applications the energy levels and the wave functions must be known. In the evaluation of S given by Eq. (7) the symmetry character of the wave functions must be explicitly introduced. It is sometimes easier to use the grand partition function

$$Z_{gm} = \sum_N \sum e^{(\mu N-E_N)/kT} \quad (9)$$

Here μ is the chemical potential and E_N is the nth level of a system having N particles. The current theories of quantum statistics, as for example the hard sphere Bose gas, are for the most part concerned with questions in this area.

The only technique now available is that of the density matrix. It is possible to express certain entities which characterize transport properties, such as the conductivity tensor, in terms of the unperturbed stationary density matrix. A complete discussion of the validity of the approximations is still lacking. In addition, once the conductivity tensor is obtained in terms of the density matrix of the stationary (but *still interacting*) system, a problem of the same order of difficulty as the evaluation of the quantum mechanical partition function remains if explicit expressions for these quantities in terms of the forces between atoms are desired.

Classical examples. Kinetic theory gave the first insight into many of the phenomena that take place in gases as well as in metals where the free (conduction) electrons can be considered as an ideal gas of electrons. The following examples illustrate some of the more fundamental calculations that have been made.

Ideal gas pressure. A classical ideal gas is described by the Boltzmann distribution of Eq. (1) (*see* GAS). The constant A is given by

$$A = \frac{N}{V}\left(\frac{m\beta}{2\pi}\right)^{3/2} \quad (10)$$

where m is the mass of an individual molecule and V is the total volume of the gas. A gas exerts a force on the wall by virtue of the fact that the molecules are reflected by it. The component of momentum normal to the wall changes its sign as a consequence of this collision. Hence if the normal velocity of the molecule is v, the momentum given off to the wall is $2mv$. To calculate the total force on a wall one needs the total momentum transferred to the wall per unit time. Let dS be a small section of the wall, and call θ the angle made by the molecule's velocity vector with the normal to dS (see Fig. 1). From Eq. (1) the number of molecules that have a speed $c = (v_x^2 + v_y^2 + v_z^2)^{1/2}$ and whose velocity vector makes an angle θ with a given axis (call these c, θ molecules) is

$$f(c, \theta) = 2\pi Ae^{-1/2\beta mc^2}c^2 \sin\theta\, d\theta dc \quad (11)$$

The number of such molecules that in time dt will collide with dS (assuming spatial homogeneity) is given by

$$dS\, c \cos\theta\, dt\, f(c, \theta) \quad (11a)$$

From this information an interesting side result may be calculated, namely, that the number of all collisions with a unit area of the wall per second is

$$2\pi A \int_0^{\pi/2} d\theta \sin\theta \cos\theta \int_0^\infty dc\, c^3 e^{-1/2\beta mc^2} \quad (12)$$

If one introduces the average speed $\bar{c}$ as

$$\bar{c} = \frac{1}{N}\iint d^3x\, d^3v\, cf \quad (12a)$$

the total number of collisions may be written as $\frac{1}{4} n\bar{c}$. Here $n = N/V$, the number density. This relation is of importance in calculating the efflux of gases through orifices. Each (c, θ) molecule contributes a momentum of $2mc \cos\theta$ to the wall per collision. Since the pressure p is given by the force per unit area, or the total momentum transferred per unit time per unit area, one obtains for p

$$p = \int_0^\infty \int_0^{\pi/2} 2mc \cos\theta \cdot 2\pi Ac \cos\theta\, e^{-1/2\beta mc^2} c^2 \sin\theta\, d\theta\, dc \quad (13)$$

$$p = \tfrac{1}{3} N m\overline{c^2} = (N/V)\beta^{-1} \quad (14)$$

Since it is known experimentally that $pV = NkT$, where k is the Boltzmann constant, $\beta = 1/kT$ is now identified. This pressure calculation is a typical example of a kinetic theory calculation.

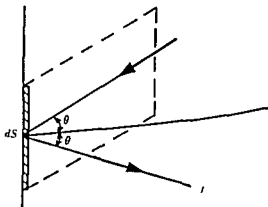


Fig. 1. Change of momentum of gas molecule as it strikes a wall; initial velocity, final velocity.

Th m a that a rela ation time describ th de ca from a tate so near a equil bri m tate th t h the molecul s ha e tra elled (on the a er age) o e m a free path the equ lib um is re establ hed Stated differe tly the no equ l b um st te i n the a rag o e c llision per m lecule rem ed f m th eq lib um tate

Exp sion (28) may ow be e aluated in terms f the mean f ee p th as

$$\text{Fo ce per unit area} = \tfrac{1}{3} nm\lambda c \frac{dt}{dy}$$

From th s, th vi ty coefficient follow d ectlv

$$\eta = \tfrac{1}{3} nm\bar{c}\lambda \qquad (33\ )$$

I trod cing the mean free p th as gi en bv Eq (30) one ees th t

$$\eta = \frac{1}{3}\frac{mc}{4\pi\ ^2} \qquad (33b)$$

Th emarkabl r lt is th t the isco ty is in deed *independ* t f the p re S ce

$$= \sqrt{8kT/\pi m}$$

the o ty d p d o th t mper t e but not n th p es e Th s m wh t unintu t result s on of the fir t t iumph f k netic th ory Both pects f Eq (33) re in g d agreement th e perim t f ot too low de t s η is in deed ndepend nt of the p essur η also p o- port o l t the squ e root of the t mperature [M DR]

B bl g phy R H Fowler *Statist cal Mech n* ic d ed 1936 D Ter Haar *El m ts of Sta tistical M ch* i 1954 C. K ttel *Eleme t ry Statist c l Physic* 1958 *s e also* STATISTICAL MECHANICS

Kinetics (chemical)

Th bra h f phy cal hem try con rned w th the mech n ms nd ate of chemi l ct n The st dy of act at on e gies of r a t o also an imp rt nt t p c n chem l ki etic.

Reaction rate The rate at wh ch chem cal re- act t re ed up or at wh ch ch m c l p oduct a f rmed is import nt t pic partı la ly ı o g n h m try nd b chem t y wh m ny d ffere t p od ts c n b obt ned all f which a pos bl acco d g t th rmodynam al l t on The p od t tu lly obt ed i determ ed by the l t rates f the comp t g rea t n The e- f e, kno ledg f r t n r tes i mp rta t in contr ll g ch m l re ts

Rat t nt The p fi te c ta t *k* is u e- f l in l l t g e ct n r t at v o s c tr t ms. If i a mple hem cal e t o $A \rightarrow B$ the t of rea t n i d ectly p oport al t the ncent t n f A th prop rt nal ty t t *k* is lled th pec fi r a t n r te t t Thu

$$\frac{-d}{dt} = kc_A \qquad (1)$$

where $-dc_A/dt$ is the rate of decrease in concen tration f A with time *t* The rate of ch nge will dec ease as A is used up and its concentratio de creases but the rate will always be pr po t onal to the concentration Thus if *k* has a alue of 0 01 per minute 1% of A which is p ese t at any tim *t* will react pe minute O er long periods of time the concent ation will be cha ging dur ng the time interval and it is nec sary to teg ate the equa tion Thus

$$k = \frac{2\ 303}{t_2 - t_1}\log\frac{c_A}{c_A} \qquad (2)$$

whe e c_A the c ncentration t time t_1 and c_A is the c ncentrat on t t me t_2 Thus it is possible to d term n th r te co stant *k* f m the measu ements of the c ncentrat on of A at tw d ffe ent times When the ate co tant has been evaluated by ex perim ntal measurements or by theoret cal calcul t ons it s poss ble to calc late accu ately the con centrat n c_A at any later t m when it i known at one tim Frequently the known concentrat on c_A i taken as the initial c ncentration start ng at zero time

Orde f r action The o d r of react n d pends on the e ponent of the concentration whi h deter mines th at of the reaction Thus in Fq (1) the eact n s first d I an th type f reaction wh ch d p nds on the collisi n of two m l cules $A + A \rightarrow A$ th rate g en by the fo mula

$$\frac{-dc_A}{dt} = kc_A{}^2 \qquad (3)$$

S ch a ct n lled a sec nd order eact n If the e ction is $A + B \rightarrow AB$ the r te of the re- action m y be g n by the relat n

$$\frac{-d\ _A}{dt} = \frac{-dc_B}{dt} = \frac{d\ \ _B}{dt} = kc_Ac_B \qquad (4)$$

The rea t on at s first o der with r pect to A and first de with r pect t B but the o rall re *actio* r t s id t be seco d o de Th r actio order i q l *to th* sum f the po nt of the conce t ti s of ll the r ti g mat rial I fi st ord r *ction k* is m ly ratio nd is i depend t of the u ts of ce trat on u d In a ec d-o d e ct wh ch d pe ds n the p od ct of the ce t t on the co st nt *k* i ludes te m f r the *con ntrat* on Its num i l al e d p d on th co ntrat n unt u d s ch as moles p liter

Wh th time *terv l i l* g it is ecess ry t tegrat d formula Th s Eq (3) b come

$$k = \frac{1}{t}\frac{x}{(\ -\ )} \qquad (5)$$

nd Eq (4) b omes

$$k = \frac{2\ 303}{t(\ -b)}\,l\ \ \frac{b(\ -x)}{a(b-\ )} \qquad (6)$$

In the case of Boltzmann statistics use of Eqs (1) (2) (10) and (24) gives

$$j = \frac{Ne^2\tau}{m} E \qquad (25a)$$

The conductivity $\sigma = Ne\ \tau/m$ cannot be compared with experiment unless the relaxation time τ is known In the Fermi case the evaluation of Eq (24) is facilitated by observing that $\partial f_0/\partial\epsilon$ has a δ function character Call $A = e^{\beta}$ so that Eq (5) reads

$$f_0 = \frac{1}{e^{\beta(\ -\mu)} + 1} \qquad (25b)$$

It is easy to show from (25b) that

$$\frac{\partial}{\partial\epsilon}\frac{1}{e^{\beta(\ -\mu)} + 1} \cong -\delta(\epsilon - \mu) \qquad (26)$$

for sufficiently low temperatures This allows the immediate calculation of Eq (24) also for the case in which the relaxation time depends on the veloc ity

Viscosity and mean free path One of the early successes of kinetic theory was the explanation of the viscosity of a gas Strictly speaking this is again a transport property and as such it should be obtained from the Boltzmann transport equa tion (20) It is possible however to give an ele mentary discussion Consider a gas that is con tained between two walls or plates the lower one ($y = 0$) at rest and the upper one constrained to move with a given velocity in the x direction (see Fig 2) A force is nece sary to maintain the con stant velocity of the plate This force is given by

$$X = \eta A \frac{dv}{dy} \qquad (27)$$

Here $dv\ /dy$ is the velocity gradient and X is the vi cous force (al o sometimes called the hear tress) on the area A which is perpendicular to the diagram (X is the component of X in the x direction) Equation (27) defines η the visco ity

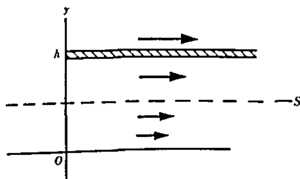


Fig 2 E pla at o of v c s ty Th plat at $y = h$ is mo ng w th eloc ty o d th plate at $y = 0$ i st t onary The ho izont l compone t of loc ty of th gas molec l s a es from 0 at $y = 0$ to t $y = h$ Mom ntum m st the efo e b t o fe red ac S by the ert c l compo nt of eloc ty

coefficient The physical rea on for this force te from the fact that molecules above the urface S have a greater flow velocity than tho e below thi surface (This will certainly be true on the a er age) Thus molecules cros ing from above to be low will carry a larger amount of momentum in the positive x direction than tho e cro ing from below S upwards Hence the net effect is a tran port of momentum in the x direction acro s the surface By Newton s econd law this will yield a force The computation can be carried out in thi manner Consider an area in the x plane The number of molecules passing through per econd is fv_yA where f is the distribution function The amount of momentum transported in the x direc tion is (per collision) $fv_yA\ mv$

The force per unit area is the sum of these terms

$$fv_yv\ m \qquad (28)$$

For the evaluation of this sum the notion of mean free path is useful The mean free path is the a erage distance traveled by a molecule between col lisions and is usually designated by λ To inve ti gate this entity imagine each molecule to be a hard sphere with radius a If a molecule moves with average speed $\bar{c}$ it sweeps out a volume $4\pi a\ ct$ in time t If there are $n = N/V$ molecules per unit volume the number of collisions per sec ond is given by the collision frequency z

$$z = n4\pi a\ \bar{c} \qquad (29)$$

For a typical gas (oxygen) under standard condi tions $n = 3 \times 10$ $\bar{c} = 4\ 5 \times 10$ cm/sec and $a \cong 1\ 8 \times 10$ cm Hence numerically $z = 5\ 5 \times 10^9$ collisions/sec The average distance bet een collisions that is the mean free path i

$$\lambda = \frac{ct}{n(4\pi a^2)ct} = \frac{1}{n(4\pi a^2)} \qquad (30)$$

Numerically $\lambda \cong 8 \times 10$ cm Th di cu ion i of cour e exceedingly crude Making the calcula tion on the basis f a Boltzmann di tribution gi es

$$\lambda = \frac{1}{\sqrt{2}\, n(4\pi a^2)} \qquad (30a)$$

Using similar methods it may be shown that the di tribution of the mean free paths (that i th number of m le ule wl o e mean free path li between x and $x + dx$) is

$$dN = \frac{N_0}{\lambda} e^{-x/\lambda}\, dx \qquad (31)$$

There i an intere ting connection bet een the mean free path and the relaxation time introduced pre i usly It should be stre ed howe er that thi c nnection f ll w more from a qualitati e discu sion than from a rig r us calculati n One would gu that

$$\tau = \lambda/c \qquad (3\ )$$

Thi mean that a relaxat on time de cribes the de- c y from a st te so near an equilibrium state tl at hen the m lec les ha e tra elled { n the er age) e me free path the equilibrium i re-establ hed Stated d fferently the nonequilibrium state s o the a erage one coll sion per molecule rem ed fr m the equ libr um state

Expres on (8) may ow be evaluated in terms of the mean free path as

$$\text{Force per u t are} = \tfrac{1}{3} nm\lambda c \frac{dv}{dy}$$

From this, the visco ty c efficient foll ws directly

$$\eta = \tfrac{1}{3} nm\bar{c}\lambda \qquad (33a)$$

Intod cing the me n free path a given by Eq (30) one ee th t

$$\eta = \frac{1}{3}\frac{mc}{4\ \sigma^2} \qquad (33b)$$

The r m kable result is that the vi cos ty is in deed independe t of the p e re Si ce

$$c = \sqrt{8kT/\pi m}$$

the visc s ty depends on the tempe ature but not on th pres u e Th s s m what unintu t e r It s o of the fir t t mph of kinet c th ory Both a pect f Eq (33) a e i good agr ement with p r m t fo t too l w d ities η i in deed i dep ndent of the pr ur η is al o proport.on l t th squa e oot of the temperature [st DR]

B bl g phy R H F wler *Statist cal Mech n i s* d ed 1936 D T r Ha r *Elem nts of Sta ts ca M hanics* 1954 C K tt l *Eleme tary Statisti l Phy s* 1958 *s e al* STATISTICAL MECHANICS

Kinetics (chemical)

Th b an h f phys cal hemistry n rned w th the mech n ms *nd at of chem al react ns* Th tudy *of* acti at n e e gi s of reaction i al.o an imp ta t t pic hemic l k *netic*

Reaction rate Th rate at wh h h m l re-a tant are u ed p or at wh h hem cal p od cts e formed an imp rt nt top c p ticularly i o g c chem try nd b hem try wh r *m ny* diff ent prod ct can b bta ed all f wh h a e po bl ac d g t therm dyn m c calculations Th prod t *et lly* bt ned det rm n d by the el ti e rates f th comp ting ctions Th e-f e, a k *owledge f* ctio at s mportant in t oll ch m cal *ct o*

R t nst nt Th pec fi rat n tant k i u e ful in c lcul t ng ct n tes at a i u tr u s. If *s imple* hem cal ct $A \rightarrow B$ th rate f r t is d re tly p po t o l t the e t u f A the pr port n l ty c t nt k is lled th pec fi re cti rate con t nt. Th s

$$\frac{-d\ _A}{dt} = kc_A \qquad (1)$$

where $-dc\ \ /dt$ is the rate of decre e in c ncen trati n of A with time t The rate of change will decr ase as A is u ed up and its concentrati n de crea es but tl e rate will always be proporti nal to the concentrati n Thus if k has a alue of 0 01 p r minute 1% of A which is pre nt at any time t will rea t per minute O er l ng periods of time the concentration will l e changing during the time interval and it is neces ary t int grate the equa tio Thus

$$k = \frac{2\ 303}{t_2 - t_1} \text{l g} \frac{c_A}{c_A} \qquad (\ )$$

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O d r of reacti The order of re cti n d pends on the expon nt of the conce tration which deter m ne the rate f the reaction Thus in Eq (1) the reaction i first ord r In a ther type of reaction which depe d on the collisi n of tw m lec le $A + A \rightarrow A_2$ the r t i g n by th formula

$$\frac{-dc_A}{dt} = k\ _A^2 \qquad (3)$$

Such a ct is c ll d second rder reaction If the reaction i $A + B \rightarrow AB$ the rate f the re-action may be gi en by the relat on

$$\frac{-dc_A}{dt} = \frac{-dc_B}{dt} = \frac{dc_{AB}}{dt} = kc_Ac_B \qquad (4)$$

The re cti n rate is fi t order with re pe t to A d fir t order w th spe t t B l t the er all re-ct on ate is said to b seco d orde The rea tio *rd s equal to th* sum of the expo ents of the o e t t ns of all the re cti g m t rial In a first-o der e ctio k is me ely a rat o a d i *j depend nt f the u ts* of c nce trat on ed I a econd ord r eact which depend on th prod ct of the c centrat ons the c n tant k ncl d *term f r th conc ntrat n* Its numerical al e depe d on the c ntrat n u its used su h s mole pe l ter

When the *t me interval is l ng t i* n ce ary to u i teg ated f rmulas Thus Eq (3) bec mes

$$k = \frac{1}{t}\frac{x}{a(a-x)} \qquad (5)$$

and Eq (4) bec m s

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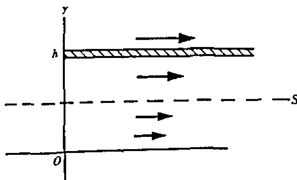


Fig 2 Explanat o of co ty Th pl t at $y = h$ mo g w th eloc ty v a d th plate at $y = 0$ is stat o ary The ho zontal compo e t of eloc ty f the gas molecule es f om 0 at $y = 0$ to at $y = h$ Moment m must therefo be transf d ac o s S by the rt cal compo nt f eloc ty

coefficient The physical reason for th force ter from the fact that molecule above the urface S have a greater flow velocity than tho e below this surface (This will certainly be true on the aver age) Thus molecules crossing from above to be low will carry a larger amount of momentum in the positive x direction than tho e cro ing from below S upwards Hence the net effect is a tran port of momentum in the x direction acro the surface By Newton s econd law this will yield a force The computation can be carried out in th manner Consider an area in the x plane The number of molecules passing through per econd is fv_yA where f is the distribution function The amount of momentum transported in the x direc tion is (per collision) $fv_yA\ mv$

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There i an interesting connection between the mean free path and tl relaxati n time introduced pre i usly It sl uld l e stre ed l wever that thi c nne ti n f ll w m re from a q ialitati e discu n tl n fr m a rigorous calculati n One would gue tl at

$$= \lambda/c \qquad (32)$$

Th m ans that a relaxatio time de cribes the decay f om a tate so n ar an equilibrium state th t hen the m lecul have tra lled (on the a er age) on mea free path the equ librium i reestabli hed St ted d fferently the n nequil brium st t s, on the average, one collision per mol cule remo ed f om the equil b ium state.

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the is o ty d pe ds on the tempe ature but not n th press Th s somewh t intuit e result w s e of th fir t tr umph *of k et c theory* B th *spects of Eq* (33) re i good gr ement with *xperime t* f r not too l w densit es η is in deed *ndep* d t f th pres ur η i also p oporti l to the qua e o t f th temperatu e [M DR]

Bibliog phy R H Fowler *Statist cal Me han cs* 2d ed 1936 D Ter Ha El *m t of Sta tistical M chan c* 1954 C. Kittel *El m tary Statist al Physic* 1958 e *als* STATISTICAL ME HA ICS

Kinetics (chemical)

The b an h f phy i al ch m st y c n erned with the mecha i m and ates f chem cal rea t on Th study of acti at on n rg es of *r ctions* s also a mporta t top in hem al k et s

Reaction rate The rate t which ch m cal eact t a u ed p or t wh h hem cal products f rm d s an imp rtant t p c part ularly gas hem try and b ch m try where ma y d ff r nt prod ts c b ol ta ned all f whi h a po ibl ac rd g t th rm dynami cal latio The p od t actu lly bt ned i det rmi d by the r l ates f th c mpet g r a t ons Th re f r a k wledg f r actio te s mp rt nt in c tr ll g hem al r a t o

Rat f i The p fic rat n tant k i u e f l cal l ting a t n at s t no s c en trations. If a imp h m l r a ti n $A \rightarrow B$ the r t of r *t on is d* tly p port onal to the entrat of A the p op t l ty t t k is c lled the pec fic act n r te c t nt. Thu

$$\frac{-d\ A}{dt} = kc_A \qquad (1)$$

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$$k = \frac{2\,303}{t_2 - t_1}\log\frac{c_A}{c_A} \qquad (\ )$$

where c_A the concentrati n at time t_1 a d c_A is the conce tration at t me t_2 Th s it is pos ble to determ ne the rate con tant k f om the m as rements of the concentrat on of A at tw d fferent times When the r te con tant has been eval ated by ex perimental mea urements or by theoret cal c lcula t ons it i possibl to calculate accurat ly the con centration c_{A_2} at any l t r t me when it is known t one t me Frequently the known concentrat on c_{A_1} i tak n a the initi l concentrati n starting at zero t me

O d of re ct on The rder f react on depend o th expone t f the concentrati n which *deter* mines the rat of the re ct on Thus in Eq (1) *the e cti n i first rder* In another type f react on wh ch dep d on the colli on of tw molecule $A + A \rightarrow A$ the rate i g en by the f rmula

$$\frac{-dc_A}{dt} = kc_A{}^2 \qquad (3)$$

Such a re cti n is alled a econd-order react n If the e ction *i* $A + B \rightarrow AB$ the rate of the re ct o *may be gi en by the relation*

$$\frac{-d}{dt} = \frac{-dc_B}{dt} = \frac{dc_{AB}}{dt} = kc_Ac_B \qquad (4)$$

The re ction rate is fi st order with respect to A and fir t de with respect to B but the er ll re- a ti n ate s said to be econd o de The *re ct on orde i equ l t* the um of th e po ents of the c *ntrat on* of all th e t ng m terial In fi *t-order rea ti n* k s merely a rat o and *i in depend* nt of the un ts of *oncentr t* on u ed In a s o d-o d r r a t on wh ch d pend on th prod u t f the c n e t ati ns th c n tant *k i clude* a term f r the c *nc ntr tion* Its numerical lue depend n the *onc ntrat* on un ts used such as moles p l te

When th *time int rv l* s l ng t i neces ary to e int grat d f rmul Th Eq (3) becomes

$$k = \frac{1}{t}\frac{x}{(a - x)} \qquad (5)$$

and Eq (4) be m

$$k = \frac{2\,303}{t(a - b)}\log\frac{b(a - x)}{(b - x)} \qquad (6)$$

where a is the concentration of A and b is the concentration of B at the start of the reaction when $t = 0$ and x is the change in concentration during time t

Third order reactions involving three substances A B and C are known but they are rather rare The rate of the reaction is proportional to the product of the concentrations of A B and C

Zero order reactions given by the formula

$$\frac{-dc_A}{dt} = k \qquad (7)$$

are known In these the rate is independent of the concentration and is constant over a long period of time Such zero order reactions are found in photochemistry where the intensity of light rather than the concentration is the rate determining factor They are found also in saturated solution where the concentrations of the reacting materials are kept constant by the solution of more of the solid

If the order of a reaction is known it is a simple matter to calculate with the formulas just listed the amount of reactant remaining or the amount of product formed at any time If the order is not known it must be evaluated from experimental data For example in the rate expression for the reaction A + B

$$\frac{-dc_A}{dt} = \frac{-dc_B}{dt} = kc_A{}^m c_B \qquad (8)$$

it is necessary to evaluate the exponent m and n Usually they will not be the whole numbers 1 2 or 3 but rather numbers such a 1 3 which then do not give *first second or third order reactions The* reaction with fractional exponents involve several reaction which take place simultaneously

In evaluating the e exponent the data may be substituted into formulas to determine if a first second or third order formula will agree with the experimental data Also the order may be determined by graphing The reaction is first order if log c_A gives a straight line when plotted against time second order if $1/c$ gives a straight line and third order if $1/c$ gives a straight line provided all reactants start with the same concentration A zero-order reaction give a horizontal line when concentration is plotted against time The order of each reactant can be determined also by increasing its concentration and measuring the effect on the reaction rate while the concentration of all other reactants are kept constant or are present in large excess

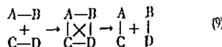
Experimental measurements Measurement of reaction rate *are made* by determining the concentrations of reactant or product as a function of time In a closed system samples can be withdrawn and analyzed immediately (or chilled quickly) so that the concentration does not change after the time of sampling The analysis may be carried out by chemical means such a titration or by physical measurement of such properties as light absorption refractive index or volume

If there is a change in pressure of a gas, electrical conductance *volume of a solution electrical* conductance or other physical property the course of the reaction can be followed in the whole reaction vessel without withdrawing sample If only one of the reactants or products absorb light of a given wavelength the changing concentration may be followed by measuring the absorption of light

In some reactions the rate is determined conveniently by passing the reacting material in a stream through the reaction chamber and determining the concentrations before and after entering the chamber The time is estimated from the rate of flow and the volume of the chamber

Activation energy *Energy must be* supplied to prepare the molecules for reaction Otherwise the reactions would take place almost instantly In ordinary thermal reactions this extra energy is provided by collisions with molecules that are moving at very high velocities Energies of about 10-100 kcal/mole are usually required to activate the molecules in reactions which proceed with measurable rates

The activation process usually involve the weakening or breaking of a chemical bond Thus in a typical reaction



energy is required to activate the molecule AB and CD and bring them so close to each other that there is a force of attraction exhibited between all *the atom The activated complex which result* may break up in different way for example into the product AC and BD

Complex molecule with many atom may be regarded as composed of many different atom pair held together either by electrical charge or by electron pair and the energies required to loosen or break these pairs and to move the atom *around* varies greatly in different chemical reaction

If the activation energy is low there are many effective molecular collision and the reaction is fast If the activation energy is high only a small fraction of the molecule will be moving fast enough to give sufficient energy on collision to activate the molecule and bring about the reaction Then the reaction is slow The distribution of molecular velocities at a given temperature is given by the Maxwell Boltzmann distribution

When the temperature is raised the average kinetic energy of the molecule increase at a rate proportional to the absolute temperature but the number of molecules with very high velocities increase very greatly Accordingly a chemical reaction proceed very much more rapidly when the temperature is raised The rate are more rapid ... of high energy The effect is large that most chemical reaction in the neighborhood of room temperature will double or treble in rate for a 10-degree rise in temperature

The Arrhe s eq t o g s the relat n be wee tı n rate and temperature thus

$$k = se^{-\Delta H_{ac}/RT} \quad (10)$$

h e k ı th pec fic e ction rate con tant e ı h b e f n t ral logarithm (2.71828) R ı the g s t t,a d T s the ab ol te t mper ture The con t t ΔH ı k wn a th he t f act t n and the c n t t s ıs called th fr q y f ctor

A d g t thı q atı n when the l g ıthm of the pec fic r t e n ta t ıs pl tted agaın t the rec p oc l f th b l te tempe ture traıght l e produ ed Th lope f thıs l e ı multıpl ed b the g c sta t R a d th c n r fa tor 2.303 t rt l g o t t l g t gı e th al e f th h t f a tı at n Th r l t hold m rk blv ll f mo t chem cal e ct e e f r mpl r ct n An x mple ı h wn Fıg 1 f the dec mpo ıt n f nıt oge pent d Wh th t t a e e l ted b m ur g k at two or m d ffe t t mp at es ıt ı po ıbl t cal lat the p ıfi r ctı n r te n ta t at ny t mpe t r wh ch th eq t h ld

The Ey g q tı n s mıl r t th mpırı l Arrhe ıu qu t n b t ıt s b ed n t tıst cal mech nd ı m re xa t It tak th f rm

$$k = \frac{RT}{Nh} e^{\Delta S_{ac}/R} e^{-\Delta H_{ac}/RT} \quad (11)$$

h re th dd tıo al t rms e defı ed f ll w ΔS_{act} ı th e t opy of ctı tı N ı the A g dr n mbe 6 0 × 10 d h Plan k s on tant, 66 × 10⁻ erg e The e t py f act a tı n a b d t rmıned ın mple e tı s f om t tı t l mecha ng d t f pect osc py a d m lecular stru t e Th t rm RT/Nh h s a alu f abo t 10 ec n r m t mp r t e

Predıct on of reaction rates R te p dıct ns e d ffı lt but few ge l rules r a a l bl f th mpl r t s. Th h f dıffı ultv l es ı the l t th t m st hem al a t s e c m pl x a d ı l ld ffe e t r a t o t kıng pl ce multa eo ly F rt t ly m t of th r

20
30
40
50
60
70
0 0029 0 0031 0 0033 0 0035 0 0037
1/T

Fıg 1 Pl t of th A h q t f th d m po t F g p t d Loga thm of th p cıf eact t pl tt d g t th p l f th bsolut t pe tu

actıons that make up tl e omplex reactı n r th m el s s mpl unım lec l r reactı ns wl ıch ın l e only ne m lecule and f llow the fı t-order rate equatıon or b m lecular reactı n wl ıch ın ol e tw m lecules and gı e a ec nd ord reac tı n

In sımple u ım lec l r reactı the fr quency factor s has a alue of about 10 ec If ıt ı much l rger a h ın r actıon ı p l al ly pres nt (s CHAI REACTION CHE ICAL) If ıt ı mall r a cha ge ı ntr py ı prob blv ı l ed ın a tı tı n In a mple l m l ul r r actı n wl ı h g es a sec d-order re tı n r te the fr ıen y factor ı cl to the freq ncy f m lecular ll t a q ntıty whı l can b al l ted l y th kı netı theory fr m kn wledg f th con trat n f m l ule a d th m lecular d ameter l l molecular eactı n t l g ompl x m lec les the cal ul tı of ll ı ns ı n t ıg f t and ıt ı neces ary t alc l te the e tropy of act atı n a ı d cated ı the Eyrı g equatı

Th heat f a tı atı n n l d t rmıned exp r ım tally from th rates at two t mp r tur nd ttempt h e been mad to est mate th m n th ba of m le lar co tant

In th est matı n f a t at n gy potent l nergy urv ar som t me d w ın whı l the energy h ldıng a p ır f t m t g ther pl tted aga nst the ı ter t mıc dı t n Th e ı mın m m ı th urve at the ınt rat m c dı t nc the mal m lec l d th en gy r q r me t r e h rply a th t m are f r ed cl t g th r A the t ms ar pulled f rtl er p rt the en rgy re q em t n ea e al o b t fı lly n ınter t mıc dı t n ı es hed whe th at m br k p rt gı ıng a h rı nt l l e nd ı d t g th t n furtl en gy ı equıred f furth paratı The h p f thı curve can b det rm ed fr m pec tr c pı data and qu ntum n mb r If thes po- t tı l e gy urve c n be pl tted ın three d m n n w th n gy l ng the e tı al x d ı ter t m d t nc betwe th t d ff r nt pa r of t ms l g th h r tal x a p t ntı l e gy s face bt ı d Th he ght of the l we t n gy pa pa t g tw v lleys c re p nd ng t t ble actant a d p d ts ı a m ue of th a tı tı n nergy

Th typ f calcul tı n f r actı tı n rgy h been att mpted ı a em empı ıc l m thod pro- p sed by H nry Ey ı g It n l er ımpl fıed lc l t o b d n th e ergy req d to b eak the t m p r bo ds a determ ed fr m c l ıme try r fr m p ct py n the ıbr t on fre qu n y d t m ed f m ınf a ed pect o py d n th te t m d t ce ı th stabl mol le A k wledg of the type of b dı g ı ec ry th t ı th fr t o f th bı dı g en gy wh h le t statı atur d the f a t wh h h m pol r lectr p b d ng The lt ha n t h ry atı f ct ry

I b mole ul tı ns d ng t a crude mp l rul pr pos d by J O H hı lde the tı t o e gy ro ghly eq al t 28% of

the energy required to break the bonds of the two reacting pairs of atoms

In endothermic bond breaking reactions a lower limit can be placed on the heat of activation It is *at least as great as the energy required to break* the bond If the rupture of the bond produces atoms or free radicals which recombine without the requirement of activation energy the activation energy is equal to the energy required to break the bond

In exothermic reactions there is no relation between the heat evolved and the activation energy It is thus necessary to rely on experimental data or rough estimates based on molecular structure or on the Eyring or Hirschfelder rules

Many chemical reaction rates are greatly affected by catalysts and by light and high energy radiation

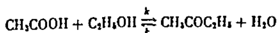
Complex reactions These are chemical reactions in which more than one reaction is going on at the same time Simple first order reactions in which the rate depends directly on the concentration or second order reactions in which the rate depends on the square of the concentration can be described in simple mathematical terms However when several reactions occur simultaneously even if they are all first or second order reactions the mathematical description often becomes very complicated The most common types of complex reactions involve reverse reactions side reactions and consecutive reactions

Reverse reactions In this type of reaction products reunite to give the original reactants



All reactions are reversible but usually the reverse reaction is so slight that it can be neglected Even if the reverse reaction is appreciable it can often be ignored in the early stages of the reaction before a sufficient amount of the products have accumulated

An example of a reversible reaction is the reaction between acetic acid and ethanol to give ethyl acetate and water



At first the rate of formation of ethyl acetate is given by the expression

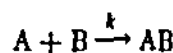
$$-\frac{dc_{C_2H_5OH}}{dt} = k_1 c_{CH_3COOH} c_{C_2H_5OH}$$

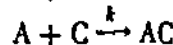
but in later stages the formula is

$$-\frac{dc_{C_2H_5OH}}{dt} = k_1 c_{CH_3COOH} c_{C_2H_5OH} - k_2 c_{CH_3COC_2H_5} c_{H_2O}$$

where k_1 is the forward reaction and k_2 is the reverse reaction It is possible to express k in terms of k_1 and the equilibrium constant K and to obtain by integration a *complete formula* for the complex reaction

Side reactions When these occur there are several ways in which the starting materials can react to give different products All are possible according to thermodynamics and the faster reaction *will predominate to give the larger yields of products* In the reaction of A with both B and C





the ratio of AB to AC will depend on the relative rates The rate expressions are

$$\frac{-dc_A}{dt} = k_1 c_A c_B + k_2 c_A c_C$$

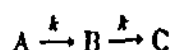
$$\frac{dc_{AB}}{dt} = k_1 c_A c_B$$

and

$$\frac{dc_{AC}}{dt} = k_2 c_A c_C$$

An example of competing or side reactions is the nitration of chlorobenzene Three different reactions take place simultaneously to give products in which the NO_2 and Cl groups are adjacent in the benzene ring where they are separated by one carbon atom or where they are separated by two carbon atoms Most of the materials react to give the third product

Consecutive reactions In this type of reaction the product of the first reaction reacts to give a second product and this in turn reacts to give a third product



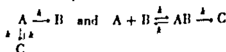
The rate at which B changes is given by the expression

$$\frac{dc_B}{dt} = k_1 c_A - k_2 c_B$$

where k_1 is the specific reaction rate constant for the decomposition of A and k_2 is the constant for the decomposition of B

Figure 2 shows a graph in which the quantities A B and C are each given as a function of time when $k_1 = 0.1$ $k_2 = 0.05$ and 1 mole of A is taken at the beginning of the reaction The concentration of A decreases rapidly at first and then more slowly but always at a rate proportional to the concentration of A It approaches zero as the *time increases The concentration of* B builds up rapidly at first goes through a maximum then decreases and eventually approaches zero The product C is slow in getting started but after B has accumulated C increases rapidly and finally approaches 1 mole which was the original amount of A It is clear that the concentration of B is a complicated function of time

There are many types of still more complex reactions for example



10 09 08 07 06 0.5 04 03 0.2 01 0
A C B
0 10 20 30 40 50 60 70
t m

Fg 2 A mpl x react o llustrat d by co t e first-ord eact s

All r made up f imple u m lec lar d b m lecula r a tio comb ation d th d ffer tial equat ns can be w tt d wn s- ily In only a few c e h weve r the e d f f t l eq ti s b l d by i t g at on The t e pr s f m ny f th mpl x r act on cann t be t g ted but ca be l ed graphically o by modern math mat l c mput g machi es

It is l th t mpl react on the o der of th t m y b g e by f ct rather than by h le umbe i t g r nd these may change d ring th o rs f the r a ti n

Olt m b mol l r rea ti s i lv g th r ti b twee tw mol les th te app ar t be th t f fi t-o d re t n F mple th hyd ly f ethyl tat wate lut n th r te f the ti n ppear t depe d o ly o th c t t of th thyl a t t becau the sol t w te in ch la g c ss that t does t pp a t ha g pp ably n am nt

Th t rmed te tep i a mpl e t b t d ed th th h lp f k n t me ment m d by ch ng g the c t t n r wid lim t h b nging the t mp t r by t g pec fic at ly t d h b t r Somet m th con t t f a t rm d te b t e ca b f ll ed by m a g t ab pt f l ght at p rt ul w l ngth wh h t b l ed by th th m t ri l p nt

M ny h m l a t o mple F m pl mpl r t u h th d t n f ga m t ri l by at lev ted t mp at s m y g th gh f ti s wh h p des l hol k t d d fi lly a bo d x de nd w t f m d S Catalysis F ee radi cal Half life Inhibitor (chemical) Kinetic theory of matter Photochemistry Potential barrier

[r n]

B bli g phy A A Fr t and R C Pear n *K t cs and M chanism* 19 3 K J La ller *Che c l Ki tics* 1950

Kinetics (classical mechanics)

Th t p rt f cl ical mechanic which deal with the relati betwe n the m ti ns of mat rial bodies and the f rc act ng upon them It i yn nym us with dynam cs of material bodie *S e* Dynamic

Basic concepts Ki etic pro eed by ad pting certain intu ti ely acceptal le c ncepts wl ich ar a ated with me ural le q ant tie The e e e tial conc pt and the mea rable q ntiti u ed for th r p cif cati n re a f llow

1 Space co f guration refer t the po ition and orie tati n f bod e i a ref rence fram ad pt d by the b erver It exp es ed quantitativ ly by an a bitrar ly ch en s t of pace coordin t of which arte n and polar coordi te are exam ple All pace rdinate re t on th notion of di t n e m a reme t

2 D ation i expre d quantit t ly by time m asured by a clock or c mparal le mech ni m

3 M ti n r f rs to ch g of c nfig rati n with time a d is expr ed by time r t of coordi ate hange called velocitie d time rate f v locity cha ge called elerat n The la ical a ump- tio th t oordinates beh e a analytic fu ct n of tim p rm t repr ntati n f l t and accelerat n a fi t and e d deri ati e re- spect ely of the sp ce oord at w th r pect to tim

4 I ert a n attr b te of bod es imply g th r ap ty t r t h ges f m t n A body in rt w th esp t to l n a m t n i den ted by t m

5 Mom tum tt f t proport l t b th the m s d l ty f a bo ly M m t m f li a m ti n i xpres d a th p od t f ma s nd li a locity

6 F er es t d gn te the i fl ence e c sed po th mot f a p rticul r body by oth r bodi not n es arily p cifi d A qua t tati co n t n betwe n the m t o f a body d th f c appl ed t it xpres ed by N wt s e o d l w f mot on wh h s d se l l t

D t time nd ma r c mm nly reg rd d f d me t l all th dyn m l qu nt t b i g d f nabl in t m of th m

Newton s second law A prim ry bj ct of J s l k t c th pred ct of th beh r f b d wh h a ubject t k w f es wh n ly n t al lues of th coord n tes a d m m nt l bl Th s ompl hed by u e f p pl fi t r g d by S J a N wto N wt s t tem t f th pr pl w e t i ted t th l m t of an de l d body alled ma p t l ha ng glig ble ext n o p

The basic dynamical law set forth by Newton and known as his second law states that the time rate of change of a particle s linear momentum is proportional to and in the direction of the force applied to the particle This statement although special in form serves as a basis for more comprehensive statements of the principle which have since appeared

Stated analytically Newton s second law becomes the differential equation

$$\frac{d(mv)}{dt} = F \qquad (1)$$

in which m represents the particle s mass v its velocity F the applied force and t the time This equation provides a definition of force and of its units if units of mass distance and time have previously been adopted The classical assumption of constancy of mass permits Eq (1) to be expressed as

$$ma = F \qquad (2)$$

where a represents the linear acceleration A particle in physical space requires three cartesian coordinates x y and z to specify its position Its linear acceleration is a vector with three cartesian components the second time derivatives of x y and z Equation (2) therefore equates two vectors requiring equality of their components expressed in detail by

$$m\frac{d^2x}{dt^2} = F_x \qquad (3a)$$

$$m\frac{d^2y}{dt^2} = F_y \qquad (3b)$$

$$m\frac{d^2z}{dt^2} = F_z \qquad (3c)$$

These are the Newtonian equations of motion of an unconstrained particle in space If the three force components F_x F_y and F_z are expressed functions of the coordinates and time the dependence of each coordinate upon the time is implied and can in favorable cases be found as solutions of the equations of motion in the form

$$x = x(t) \qquad y = y(t) \qquad z = z(t)$$

The primary objective of kinetics is achieved in the discovery of such functions

One dimensional particle motion The motion of a particle which remains on the x axis either because of constraint or initial conditions is determined by Eq (3a) alone which is simplified by the absence of y and z Such one dimensional dynamical problems provide an attractively simple introduction to the subject Examples are the motion of a body falling vertically subject to gravitational force and linear harmonic motion

Two dimensional particle motion The motion of a particle remaining in the plane of the x and y axes is determined by Eq (3a and b) from which z is absent Two dimensional problems are reasonably tractible and include many of physical interest such as the motion of a projectile (exterior ballistics) and of a body attracted toward a central point as in planetary motion Solution of a two dimensional problem is frequently simplified by change of variables which reduce it to a pair of one dimensional problems

Three dimensional particle motion All three equations of motion (3a b and c) apply to an unconstrained particle in space Complete solutions are possible only when the functions expressing force components are relatively simple in character Fortunately many of the solvable cases correspond to important physical examples in which simplicity of the forces allows separation into one and two dimensional motion Three dimensional projectile motion without friction is an example

Newton s third law The behavior of systems composed of two or more interacting particles is treated by Newtonian dynamics augmented by Newton s third law of motion which states that when two bodies interact the forces they exert on one another are equal and oppositely directed The important laws of momentum and energy conservation are derivable for such systems (the latter only for forces of special type) and useful in solution of problems The equations of motion for systems of more than two interacting particles in space are mathematically intractible in the absence of geometrical constraints or special initial conditions but assumptions approximating the physical situation permit solution of many problems of physical interest The principles of particle dynamics are transferred to extended bodies by regarding them as systems of particles subject to specified mutual constraints and mutual forces *See* RIGID-BODY DYNAMICS *see also* ACCELERATION BALLISTICS EXTERIOR FORCE GRAVITATION HARMONIC MOTION MASS MOMENTUM ORBITAL MOTION VELOCITY

[R A F]

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King snake

Any of several species of the genus *Lampropeltis* seven of which occur in the United States This is a group of moderate sized snakes all of which are constrictors and are separated into distinct groups by a common scale pattern however the species are highly diversified in color *B t known is L getulus of the s uth rn United* States It is here in [illegible] there are nine recognized subspecies [illegible] the common [illegible] black form which is marked with fine speck of yellow [illegible] all [illegible] and [illegible] king snake Other [illegible] banded [illegible] in gray [illegible] The milk snake *L d lata* [illegible] usually [illegible] with [illegible] distinct

f rms, but us ally tr gl) banded with red bl k d y ll w and ı ften nfu ed with tl e d dly c al ake (s CORAL SNAKE) The milk ke c mmo e t of the R cky Mo t ın b t s hy a d eld m een

Th name king ke come from the hab t f me sp ıes of att cki g and k ll g otl nak m l d g p o ous sp ıes *See* SQUAMATA

[J D B]

Kingbird

A flycat her *Ty n ty n us* of the f mily Tyra nid e Th ıs famıl r summer r ad de b d o r m ch of east n North Ame ıca ıt ıs also f d t O eg N ad and New Me ı It ı sl te g a abo e nd wh te b low The cr wn of ad lt h s a c n led o nge p tch The taıl ı bl k t pp d by b nd of wh t The kingbırd



Th k gb d *Ty ty* l gth to 9 l (F m E L P lm F ldb k f N t l H st ry M G w H ll 1949)

p h f es d h ubs f m wh ch ıt lıes f rth t p ck ın ets ut f th a r It metım u ly p y up h neyb e nd s f q tly ll d b m rtı r bee b d b u f th h b t S FLYC TCHER PASSERIFORMES

[J D B]

Kingfisher

Any f 86 pe e f the t lly o mop l t famıly Al ed n d e The s ly ne p s ı th Unı t d State *M g yle lcy* the b lted kı gfı h It m wh t m l r t th bl e jay b t l g r bl g ay b e d wh te b l w d has a gged t Th b lted k gfi h r n st n h l d g ın t cal b k met m s q t a d s t ce f m w t It cc r m t f N rth Am rı a estı g p c a d w te f m th e t l t te uthwa d t Ce t l Am rı

Th k ngfi h d f m a p ed pe h the w t d e t h m ll fi h w th gr t ccu r y It solıt ry d lw y fi he l nd w ll



Th b lt d kl gfi h *M g ryl alcy* l gth to 14) l (F m E L P lm F ldb k of N t r l H t y M G w H ll 1949)

n t t ler te a tl er k ngf h r within ıt t r ıt ry *Se* CORACIIFORMES

[J D B]

Kinglet

Any on of se n spe ıe of sm ll so gbird f th family Syl ııd e the Old World warbl r Tw species o cu ı N th Ame ıca Fx pt f r th hum m gb d thes r the m ll t f all N rth



Th ruby-c w d k gl t *R g l l d l* l gth t 4⅗ (F m E L P lm F ldb k f N t l H s t ry M G w H ll 1949)

Am ı a b d c ely h lf th f a p rrow They a e h g r mı l g me f the m re b u e w rble s nd h e a ha cter stıc n rv u twıt h g f th w ngs s th y fl t ab t thr gh t et ps o bu he The c wn f the head m y be l rl t y ll w d black y ll w a ge a d bl k

K gl ts n t th b l e d w te f m the t l t t s uthwa d S P SSERIFORMES

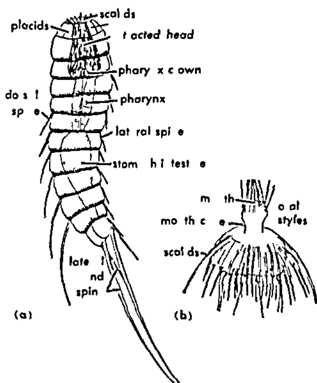
[J D B]

Kinorhyncha

A class of the phylum A chelminthes con i ting of superficially egmented micro copic marine ani mals lacking external ciliation All members of the class are benthonic o called becau e they *generally dwell on mud bottoms in shallow water* in the littoral zone

Three suborders are generally recognized Cyclo rhagae Conchorhagae and Homalorhagae

The body is completely enclosed in a transparent cuticle secreted by an underlying epidermis As is the ca e among the Nematoda the cuticle is periodically molted during growth Three major regions of the body are recognizable head neck and a jointed trunk The apparent segments of the body are termed zonites the head and neck each consist of one zonite Except for one genus in which the trunk has 12 zonites the usual number is 11



Ech od rella sp o cyclo hago k o hy ch ( ) S de iew (b) Head (*After L H Hyman The I ert b ates* of 3 McG aw H ll 1951)

The head is completely retractal le When pro truded it bears 5–7 circle of spine called scalid

The neck is covered by a varying numl er of large plates called placi l Only am ng tl e Cy clorhagae do the placid cl e over the end of the body when the head i withdrawn Among the Conchorhagae the clo ing apparatu c n i t of a pair of lateral plates on the third zonite while in the Homalorhagae it con i t of a single dor al plate and three ventral plate on the thir l z nite

A pair of ventral a lhe i e tube occurs on either the third or fourth zonite Each of th re ... h z nites u ually l ears a pair of

terminal zonite may bear in addition a pair of large movable lateral pine

The musculature is egmentally arranged There are two pairs of longitudinal muscle bands a dor olateral and a ventrolateral Anteriorly these form the retractors of the head Protru i n of the *head is accompli hed by contraction of the ring* mu cles of the fir t two zonite and the paired dor oventral mu cle bands in the trunk zonites

Locomotion is accompli hed in the follo ing manner the head is protruded and the urface gripped by the calid The trunk i then advanced by contraction of the longitudinal mu cles and the head is retracted Repetition of thi equence re sults in creeping locomotion

The nervous sy tem con i ts of a brain which encircles the anterior end of the pharynx a ventral *ganglionated cord and in addition* ganglion cell in each zonite are located in the lateral and dor al epidermal chords

The mouth is terminally located on the mouth cone which enclo es a short buccal cavity Po te rior to the buccal cavity is a mu cular pharynx The pharynx is imilar to that of the Nematoda and Gastrotricha but differs in being lined by a syncytial epithelium The pharynx is followed by a hort slender e ophagu who e epithelial lining is continuous with that of the pharynx The tomach intestine is a straight simple tube covered ex ternally l y a loo e network of mu cle fil ers The hort endgut is separated from the tomach intes tine by a phincter A second more po teri r spincter is al o pre ent The anu is terminal

The fluid filled body cavity l etween the dige ti e *tract and the epidermis i unlined and* i pre umably a pseudocoele or fal e coelom

A ingle pair of protonephri lial excretory organ is pre ent in the tenth zonite The flame l ulb are multinucleate and generally each contain a ingle l ng flagellum Among the Homalorhagae a sec ond short flagellum i pre ent The *protonephridial* canal which lea l t nephri liop res on the elev enth z nite contain lriving flagella The pores c n i t of sie e plate

The Kinorhyncha are di eciou In each sex there i one pair of gonad The genital p res are l cate l on the thirteenth zonite The ovary c ntain l th ova an l nutritive cell A hort ovi l uct ex tend from the po terior en l of each ovary t th genital pore The male genital pore is armed with two or tl ree penial picule which may serve a a copulat ry apparatu

Tl e early eml ryology of the Kin rhyncl a is un kn wn In the Cyclorhagae the egg hatch int a minute larva which lack external evi lence of z nite hea l pla i l pharynx or anu Tl i l rva pa tl rough s eral ucce ive stag eparated l y m lt during which the numl er of z nit in er a an l a lult m rph logy i attaine l Am ng tl H mal rl aga tl fir t larva ha 6 7 z nites an l i in g neral a m re a lvance l larva than tl at f the Cycl rl agae Th dev lopment of th Conch rl agae i unknown S e A HELMINTHES

Kirchhoff s laws of electric circuits

Fundamental atural laws dealing with the relati n f currents at junct n and tl e oltages round a loop these la s are mmo ly used in the analy is and solution of n tw rk They m y be u ed directly to sol e ci cu t p oblems, and they fo m the basis fo n tw rk theo em used w th mo e complex net rk M y ye rs of e perience ha e pro ed the x ctne s of th se l ws

In the solution f ci cuit problems it is neces sary to identify the spec fic physic l pri c ples invol ed in the p obl m a d on the basi of them t write quat s expre sing the relati ns among the nknowns Physically the analysi f networks is ba ed on Ohm s law g ing the bran h equati ns Kirchhoff's ltage law g ng the loop voltage equ ti ns, and Kirchhoff's current law givi g the nod c irr nt equations Mathematic lly a netwo k m be sol ed when it is p s ble to et up a n m ber of independe t equ ti s equal t the number of unknowns. *See* CIRCUIT ELECTRIC NETWORK THEORY ELECTRICAL.

When wr t ng the nd pendent eq tio s current directi ns and olt g pola it es may be cho en arbitrarily If the equ tions are written with due g rd f r these arb trary cho ces the algeb ai s g of curr nt and oltage w ll take c re f them sel es.

Kirchhoff s voltage law O e way of stating Kirch ff's oltag law i At ea h in tant of time th algeb a c um of th olt ge r is q al to the alg b a m f the olt ge dr ps both being taken in th s me d rect n rou d the cl sed loop

Th ppl ati of th s l w may be ll trated th th c u t F g 1 F r t, t s d able to on d the gnificance of a ltage ri e d ltag d p I t n to the urr nt ar w The (R g defin t ns a ill t ated by Fig 1

A ltag rise n nt ed f i g i g f m l 1 2 n th d ect n of the urr t arr w the pol r ity f om m u t pl Th s E i v ltag r se fr m l t 2.

A lt g d op i e c u te ed f g i g f m 3 to 4 n th d ect n f th rr nt arr w the pol rity f m plu t min s Thus e $= R i$ s a l ag d p f m 3 to 4

The ppl at o f Kirchh ff's ltage l w g es the loop ltag equ t n

$$E = \quad + \quad = R i + R i$$

In th n tw rk f F g 2 the ltag ur s ha e the m f qu ncy The pos t s fo the b h curr t I I and I e cho e rb t a ly a e th loop rr ts I nd I The ltage equ tio s f loop 1 d 2 c b wr tte g n ta t e b ch urr ts st t n l op curr nt ph sor b h c rr t ph loop rts

The loop lt g qu t obta ed by ap plying K hh ff ltag l w t ea h loop s f l lo

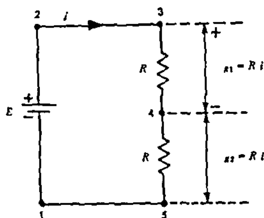


Fig 1

Using in tanta eous bra ch currents

$$e_1 = Ri_R + L\frac{di_L}{dt}$$

$$e_2 = \frac{1}{C}\int i_C\,dt + L\frac{di_L}{dt}$$

Usi g instantaneou l p current

$$e_1 = Ri_1 + L\frac{d(i_1+i_2)}{dt}$$

$$e_2 = \frac{1}{C}\int i_2\,dt + L\frac{d(i_2+i_1)}{dt}$$

Us ng ph or branch current

$$E_1 = RI_R + j\omega L I_L$$

$$E_2 = -j\frac{1}{\omega C}I_C + j\omega L I_L$$

Usi g pha r loop currents

$$E_a = RI_1 + j\omega L(I_1 + I_2)$$

$$E_2 = -j\frac{1}{\omega C}I_2 + j\omega L(I_2 + I_1)$$

Kirchhoff s current law Kirchhoff's current law m y b expre s d as follows At any gi en n t nt the sum f th n ta t neo s alues of all th cu rents fl w ng toward a po nt equal t the s m of th inst nta eous value f ll the curre ts fl wing away f om th p int."

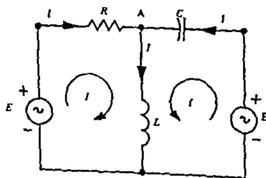


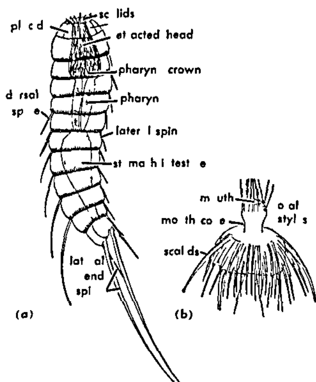
Fig 2

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Ech nod rella sp a cyclo hagous k orhynch (a) S de v ew (b) Head (After L H Hyman *The In erteb tes* I 3 M Graw H ll 1951)

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A pair of ventral adhesive tubes occurs on either the third or fourth zonite Fach of tl e re maining trunk zonites usually bears a pair of lateral spines and a single dor al spine The terminal zonite may bear in addition a pair of large movable lateral spines

The musculature is segmentally arranged There are two pairs of longitudinal mu cle l and a dorsolateral and a ventrolateral Anteriorly these form the retractors of the head Protrusion of the head is accomplished by contraction of the ring muscles of the first two zonites and the paired dorsoventral muscle bands in the trunk zonites

Locomotion is accomplished in the following manner the head is protruded and the urface gripped by the scalids The trunk i then advanced by contraction of the longitudinal mu cles and the head is retracted Repetition of this sequence re sults in creeping locomotion

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The fluid filled body cavity between the dige tive tract and the epidermis is unlined and is pre sumably a pseudocoele or fal e coelom

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The Kinorhyncha are dioecious In each ex there is one pair of gonads The genital pores are locate l on the thirteenth zonite The ovary contain both ova and nutriti e cells A hort oviduct ex tends from the posterior end of each ovary to the genital pore The male genital pore i armed with two or three penial spicules which may erve as a copulatory apparatus

The early eml ryology of the Kinorhyncha is un known In the Cyclorhagae the eggs hatch int a minute larva which lacks external evidence of zonite head placid pharynx or anu This larva pas e through everal ucce si e stage separated l y molt during which the numl er of zonites in crea e an l adult morph logy i attained Among the Homalorhagae the fir t larva has 6–7 zonite and i in g neral a more advanced larva than that of tl e Cyclorhagae The devel pment of the C ncl rhagae is unknown *S e* C IFIMINTHES

[M S]

Kirchhoff s laws of electric circuits

Fu d m t l natural laws d al g with the relatio f currents t a ju ct on a d the v ltages arou d a loop the-e la are c mm nly u ed in the naly i and solution of netw rk They may be u ed d rectly t sol e c rcu t p oblem and they f rm the ba i for etwork theor m used with more complex net orks. Ma y year of exper e ce ha e pro ed the ex ctness of these laws

I the olut n of c cu t p oblems it is ne es sary to dentify th pec fic phys cal principles in l ed in the probl m and on the bas s of them to write equ ti s expre si g the relations among the u kn wns Phys ally the analysis f networks ba ed n Ohm law gi g the bra ch equat on Kirchhoff's ltage law g i g the loop voltage equati n a d Kirchhoff's current law g ing the nod rr nt equati M thematically a network may be l d when t s possible t set up a num be of independent equat ns eq al to the numbe of unknow s See CIRCUIT ELECTRIC NETWORK THEORY ELECTRICAL.

Wh n riting th ind pend nt equations current directio and olt g polar tie m y be ch en a bitra ly If the q ti ns are written with due r g d f thes rbitrary cho the algebraic gn of curre t and lt g will t ke care of them sel es.

Kirchhoff s voltage law O wav of tating Kirchhoff oltag law i At e h in tant f t me th lg b m of the oltag i e is qu l to th lgebrai s m f the ltag d op both b ng taken in the same di t on a u d the cl sed loop

Th appl c t o f th s law may b illu trated with the irc t in F g 1 F rst, it des ble t co d r the gn fi nce of a v lt ge i a d ltage d p n elat t th rrent r ow The f llowi g defi ti n re Ilu trated by F g 1

A ltag ri s e t red f goi g f om 1 to 2 in th d ect f th curre t a ow the p l r ty i f m m n t pl Th E a olt g rise fr m 1 t 2.

A lt g dr p o t ed if in g ng fr m 3 t 4 th dire tio f the current rr w th pol ty f m plus t m u Thu v = R a ltage drop fr m 3 t 4

Th ppli at n f Ki hh ff's ltage law g s the loop olt g q t n

$$E = \quad + v \quad = R \quad + R$$

I th n tw k f F g 2 the olt g ou h th ame f eq e cy Th p t n f r the b anch urre t I I_L d I ar ch s n b t r ly e the loop rr nt I d I The ltag equ t f lo ps 1 d 2 n be wr tte u i g t nta eou b h e t st ta e s l op c rr ts ph so b h cu t pha r loop rre ts

Th loop lt g quati n a bta ed by ap pl g K hh ff lt g law t e l l op f l

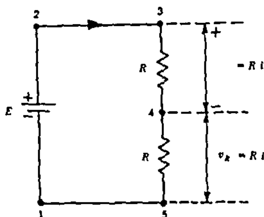


Fig 1

Usi g instantaneous branch currents

$$e_1 = R_R + L\frac{di_L}{dt}$$

$$e_2 = \frac{1}{C}\int i_C\,dt + L\frac{di_L}{dt}$$

Using insta taneou loop current

$$e_1 = Ri_1 + L\frac{d(i_1 + i_2)}{dt}$$

$$e_2 = \frac{1}{C}\int i \; dt + L\frac{d(i_2 + i)}{dt}$$

Using phasor branch curre ts

$$E_e = RI_R + j\omega L I_L$$

$$E_2 = -j\frac{1}{\omega C}I_C + j\omega L I_L$$

U g ph sor loop currents

$$E = RI_1 + j\omega L(I_1 + I_2)$$

$$E_2 = -j\frac{1}{\omega C}I + j\omega L(I_2 + I_1)$$

Kirchhoff's current law K r hh ff's *current law* may be pres ed s f ll w At ny g en insta t the m f the in t tan o val es f all the cur ents flowing t w d p nt is equal to the sum of th tant eo s al es of all the curre t flowi g way f m the po nt.

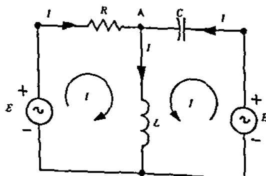


Fig 2

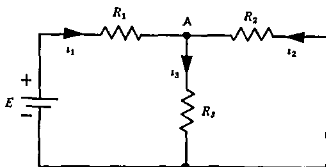


Fig 3

The application of this law may be illustrated with the circuit in Fig 3 At node A

$$i_1 = i_2 + i_3$$

The current equations at node A in Fig 2 can be written using instantaneous branch currents or *phasor branch currents*
Using instantaneous branch currents

$$i_R + i_C = i_L$$

Using phasor branch currents

$$\mathbf{I}_R + \mathbf{I}_C = \mathbf{I}_L$$

[K Y T]

Kissing bug

A name sometimes limited to a single species *Reduvius personatus* but usually applied to any of several members of the family Reduviidae order Hemiptera They are also called assa sin bugs cone nose bugs or big bedbugs Several of the e species may be found at times in houses and may inflict very painful bites They eat other insects Several species are known to be vectors for the trypanosome parasite that causes Chagas disea e in South America and others are suspected as vec tors for kala azar in India *See* CHAGAS DISEASE HEMIPTERA LEISHMANIASIS [J D B]

Kite

A tethered flying device that supports itself and the cable that connects it to the ground by means of the aerodynamic forces created by the relative motion of the wind This relative wind may ari e merely from the natural motions of the air or may be caused by towing the kite through the agency of its connecting cable

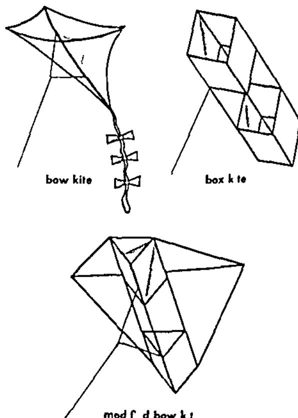
Kites take many forms the bow and l ox kites shown in the drawing are common in the United States In many countries particularly in Asia kites are frequently used in rituals and fe tivals their bizarre forms and shapes are traditional ome having been developed centuries ago

The lifting force of all kites is produced l y de flecting the air downward the re ulting change in momentum producing an upward force To l e uc ce sful a kite must have an extremely l w wing loading (weight/area) so that it may fly e en on days when the wind velocity is not high It mu t be completely stable since the only control available to the operator are the length of cable and the rate at which it is taken in or let out Efficient design requires that its lift to drag ratio be as high as po sible

Experiments on the possible application of efficient aircraft type lifting surfaces in which most of the lift arises from the low pres ures created by the air flowing over the upper surface have hown them to be too sensitive to changes in wind force and direction Under normal atmo pheric conditions the use of this type of lifting surface re ults in a kite that behaves in a violent and un predictable manner For this reason the higher drag associated with a surface from which the flow has separated is tolerated and the majority of the lifting force is obtained from pre sure on the lower surface because stalled surfaces are much less sensitive to wind changes

Both the lift to drag ratio and the tabil ty of the kite are functions of the length of cable The more cable relea ed the more drag created Thi combined with the increa e in weight being up ported causes the kite to ag off downwind re ducing the flight angle which is the angle formed between the horizontal and a line pa ing through the kite and the oj erator

Most kites with a properly located cable pivot point generally slightly ahead of the center of gravity demonstrate longitudinal tability Lateral and directional instabilities generally couple to produce violent motions The longer the cable the more the e motions are damped Lateral and direc



Commo fo ms of kite

t n l t bility are impr ed by the u f effecti e dihed l (th bow of the bow kit) d a fle ble tail h h p o de both d ectional t b lity and d mpi g [D C H]

Kiwi

A f e eral pecie f prim t e fl ghtle s ter restr l bird f th rde Apt rygiform There i b t o e l ing g u *Apt ry* l mited t New Z al d They h e l g l der b ll and ar c ered th loos hair l ke f thers The w g i de g t b ne t ctu e a well s in the sb n e

i kwi (F m E L P lm F ldb k f N t l H s ry McG o -H ll 1949)

l fl ght f ath Th p i r nge from h to 2¼ ft n l gth Th v t t orm nd n l K i e r with g e t pe d All th pec e e octurn l d d k l r The n t a b le t th f t f t e nt n a ingl urge g S APTERYGIFORMES [J D B]

Klebsiella pneumoniae

A gr m egat rod h ped b c llu b l g g t h family E e b t a e e (ENTEROBACTE IACEAE) It al o kn w F edland r b cllu Th m oo gan m m t l s ally p ted, d p od es la g m unt of l my extr cell l m t al *K pn m* th u at agent f a p rt la ly ev p m n n n d oc s lly es loc l ed p ul t nfe k n man d an m l It is ptibl to ther apy by ma v t b t (s ANTIBIOTIC)

P esent (1960) p on l fies *Kl b ll* a g n sepa t f m *A b ct* [A J W]

B bl g aphy E H m h a d P R Edwa ds *I t Bull B t i l N m T x* 10(2) 71 4 75 1960

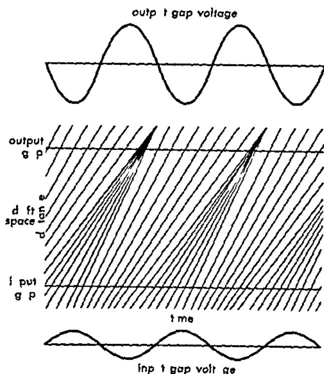
Klystron

A type of lect on t b d f mplifi t o g t f d w es th m c ow e g f f qu es It ut l ze the v lo ty m d l t p pl el t o f a b m b g r d e- loc ty by th d o-f quen y (rf) olt g ppl ed a an p t g p f ca ity es n t D ft g a t th t ke pla th t th l ty variati ns are converted t current ariati ns and th current i turn induces an output a ro a gap to a cavity reson tor (ee ELECTRON MOTION IN VACUUM) The kl tro tub i a high gain narrow b nd tul e with po sible effic encies from l w t moder te a d a ds the lim tatio s of g id c n trolled tubes at the microwa e f e j en ies by mak ing use of tra it time effect f ele tron rather th n b ing degr ded in perf rma ce by th m See MICROWAVE TUBE

A chemati diagram of a mple klystr n tube i hown in F g 1 An ele tr n stream is prod ced l y a thermionic cath de and focu ed by the auxil ary lectrode of the electr n gun and in some high p wer kl tron l y f c ing magnet producing a mag et field n the d ect n f the electron t eam S gnal at m w e f eq en ies are ap pl d t th inp it reso ant ca ty Th e produ e an rf v ltag ac s the inpi t gap (s met mes all d the l t che) whi h i ft n gridded t local ze the rf fi lds acting n the electr n be m Thi applied rf ltage cau e lectro t l e ac celer ted by the f field for a half cycle and de celer ted f the r m ni g half eycl Th beam the enter a tant p tential drift r gi n wher th f t lectr t nd to catch up with the sl w ne th p d g l h f l arge in the beam t x t f om thi d ft eg n The b nched beam pa es thr ugh ec d gap (which i al fre quently gr dded) er wh ch an rf irre t in duced a d th p du es u f l outp t p wer by fl w g i th at d itp t cuit (som times lled th at h) Th elect on be m aft r pas age th ugh the sec nd g p is coll ted on a col lect r lect de

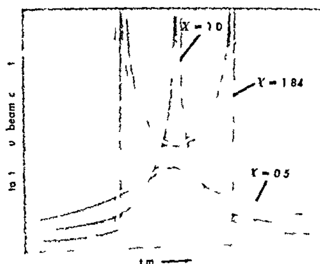
T ill tr te the l ching ct o n a kly tron th Appleg te d am f F g 2 is s mpl and u e- f l Thi a d t t m rs f th drift space the d te be g pr p rt al t d st nce l g

Fg 1 S h m t d g m of tw -c ty kly tr mpl f (m l p t h w)



F g 2 D stance t me (Applegate) d agram for a klys tron llustrat ng the bunch ng action in a drift space

the drift tube and the abscissa being proportional to time The curve for a given electron is a straight line in the field free drift space the slope of the line being proportional to the velocity at entrance Figure 2 shows a number of such lines each for a different electron entering at a different time and so with a different velocity depending upon the pha e of the rf wave across the input gap at the time that electron passed through The diagram demonstrate how the faster electrons (greater slopes) catch up with the slower ones (smaller slopes) At ome di tance such as A marked by the dotted line definite bunches are formed so that an output circuit might be placed for induction of the



F g 3 Wave shapes of current ersus t me for a deal zed klyst on neglect g space cha g X b ch ing p amete nd cates the deg ee of bu ch g

desired output Figure 3 shows pictures of the wave shape of current at various positions in the drift space for an idealized model as above It is to be noted that the current wave shape is rich in harmonics

The transfer admittance (analogous to the transconductance of a triode) of the idealized two-gap klystron is given by

$$y_m = \frac{j\theta I_0}{2V_0} e^{-j\theta} \left[\frac{J_1\left(\frac{\theta V_1}{2V_0}\right)}{\left(\frac{\theta V_1}{4V_0}\right)} \right] \tag{1}$$

where V_1 is the effective ac gap voltage J_1 i a Bessel function of order one θ is the transit angle in drift space in radians I_0 is the dc beam current and V_0 is the dc beam voltage This transadmittance is ordinarily low compared with the tran conductance of triodes and tetrodes so a high impedance is required in the output circuit u ually a cavity type circuit As input gap loading is small the input circuit is usually a similar high impedance cavity circuit Both of these usually have a high quality factor Q which represents the ratio of energy stored to that dissipated per cycle leading to a relatively narrow bandwidth The value of tran admittance given by Eq (1) may be decrea ed by space charge effects in high density electron beams The e effects cau e both a longitudinal and transverse debunching of electrons Finite tran it time across input and output gaps or the u e of gridless gaps further decreases the tran admittance by the introduction of gap factors less than unity in the equation These latter effects al o d crease the value of gap impedance so that smaller power gains are obtained

Circuit The resonant circuit used in both the input and output gaps is normally of the resonant cavity type (*see* CAVITY RESONATOR) Because of the desirability of keeping gap transit time to a low alue the cavities are normally axially symmetric with a small gap in the vicinity of the axis where the beam passes Coupling from the cavity may be by loops probes or irises with the fir t of these most common

A given re onant mode of the cavity re onator nay be represented by three parameter

f = re onant frequency

Q = quality factor = $2\pi f \times \frac{\text{energy stored}}{\text{a erage power lo s}}$

R_{sh} = maximum shunt resistance acro gap at resonance

For the output ca ity which is coupled to a u eful load the loaded Q_L becomes an important fourth parameter The Q is al o related to the bandwidth of the circuit Δf between half p wer point

$$Q = \frac{f_0}{\Delta f} \tag{2}$$

Klystron amplifier The b ic two-ca ty t be of g l h be n desc bed as an amplif r The lt ge g of ch a mpl fier ı gı en by

$$G = \left(\frac{P}{P_{in}}\right)^{1/2} = \left[\left(\frac{\theta I}{2I_0}\right)^2 \frac{R\ I^2}{2} \frac{2R_k}{I_1^2}\right]^{1/2} = \frac{\theta I_0}{2I_0} R_k \quad (3)$$

h bandwidth f the ampl fier ıs

$$\Delta f = \frac{f}{Q} \quad (4)$$

fh th g ı bandw dth product ıs

$$G\Delta f = \frac{\theta I_0 R_{sh} f_0}{2I_0 Q} \quad (5)$$

H gh gain may be p od ed at the expense of band dth by ıng a circ t with h gher Q and c ers For a gı en tube the best g bandw dth p od t ıs obt ıned w th a cı cu t with the highest al e of R_{sh}/Q whı h ı frequently taken a a fig ur f merit f r kly tr n cır uıts

Kly tro with gr ter ga bandw dth product than pos ble from two-c ty e s n may be made by u g add tıo al cav tıes a d tagger tun ıng among the ca t A mult a ıty klystron ı ıl lu tr ted ın Fıg 4 Bandwidths of 5% ha e been ob ta ned f m h gh p wer kly tr ns of the multı ca ıty type

Fig 4 Sch m t d g m f m lt ty kly t pl fi (vo m l p t h w)

Fg 5 Sch m n d g m f tw-c ty kly t oscıll t w h f db k b tw

Klystron oscillator The sımplest c nceptual klystro oscıllator ıs obtaı ed by addı g exter l feedba k p th t the two-cavıty klystro ampl fi ll t ted by Fıg 5 Th ph se a d amo t of f dback mu t be pr p r for o ıllatı al th gh f q e cy a d powe level c shıft l ghtly t mpe s te f r m ll ıatı s from th ıdeal feedb ck o d tıo S h a two-c ıty scıll t r ery stable b t ı t ften u ed a t ı sually m bulky and tıve t dj tment than a m g t n f c mp ble p we le l

Reflex klystron oscillator Th s ıs mpl f l dev In th klystr n o ca ty t ke o th f t of both bu he a d tch Feed b k ı obt d by mea f a r pelle ltage n fl ctıng l ct de wh h et rns the b m to the a ty The f q y f th de e ı t able o r th ge f bo t p ce t by cha g of th p ller lt ge It ıs ed s f que cy m d l ted so r o n sc ll t fo u e n t m tı freq cy t l y tem Mo t eflex sc llator l w p w r d s (p w ı m llıwatt) a d u t bl f r l l llat s, alth gh me p od e pow of the d f w tts Ampl fıcat n m lly pr d d f ll w ng br adb d t ges ıf h ghe p we l l a d ed a ın n FM t m tt

F gu 6 how th d g m f a typ l eflex kly t Th beam le th g the al way d p th gh the gle t ed ty wh t el ty mod l t d th b n h f a two- ty kly tr mı g n rf lt ge s th

Fıg 6 D gram f fl kly t o o c ll to Thi d ıg ill tr t s el ct path which mo d ft t rn th gh the g p

gap The bunching action in this case takes place not in a field free drift region but in the retarding field region between the cavity and the repeller the latter being at a negative dc potential In this retarding region the fast electrons penetrate farther than the slow ones so that there may be bunching when electrons are returned to the cavity as shown by the Applegate diagram or distance time plot in Fig 7 If the phase of the returned bunches is correct the current induced in the cavity reinforces the original voltage building up an oscillation until nonlinear effects produce a limiting action

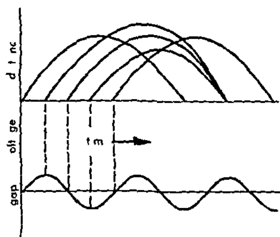


Fig 7 Distance time (Applegate) diagram for a reflex klystron demonstrating the condition for oscillation

The correct phase for oscillation is found to result when the time of transit θ (out and back) of the average velocity electron represents an integral number of cycles N plus one fourth

$$\theta = (N + \tfrac{1}{4})2\pi \qquad (6)$$

There are different electronic modes corresponding to the number of the integer N About each value of N oscillation will continue for a small region with variation of transit angle A typical result of varying repeller voltage is shown in Fig 8 The

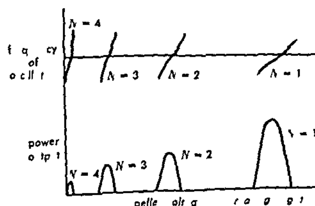


Fig 8 Frequency and power output curves as a function of repeller voltage for a typical reflex klystron demonstrating various electronic modes of oscillation

mode with lowest N is at the highest value of (negative) repeller voltage and is the broadest mode It may or may not be the strongest mode depending upon the strength of coupling to the load but if not the adjacent one will be the strongest and higher order modes (lower values of repeller voltage) will decrease in strength The total tuning range is nearly the same in all modes so the tuning rate in megacycles per volt is greater in the higher order narrower modes

If electrons are allowed to make more than one transit a hysteresis effect may be observed in that different tuning curves are obtained for increasing or decreasing repeller voltage in a given mode The careful design can eliminate this possibility in tubes for which it would be undesirable The sketch of Fig 6 indicates the design for collection of electrons after one transit

Reflex klystrons following these basic principles have been built for frequencies from 500 to 75 000 Mc [J R W H]

Bibliography D R Hamilton J K Knipp and J B H Kuper *Klystrons and Microwave Triodes* 1948 A E Harrison *Klystron Tubes* 1947 J R Pierce and W G Shepherd Reflex oscillators *Bell System Tech J* 26 460–681 1947 R H Varian and S F Varian A high frequency oscillator and amplifier *J Appl Phys* 10 321 327 1939 D L Webster Cathode ray bunching *J Appl Phys* 10 501–508 1939

Knudsen number

In fluid mechanics the ratio l/L of the mean free path length l of the molecules of the fluid to a characteristic length L of the structure in the fluid stream When the mean free path of the fluid particles is short relative to the size object being considered the fluid can be treated as a continuum (see FIELD THEORY CLASSICAL GAS DYNAMICS) If the path length between molecular encounters is comparable to or larger than a significant dimension of the flow region the gas must be treated as consisting of discrete particles (see STATISTICAL MECHANICS SUPERAERODYNAMICS) The usual classifications of flow according to Knudsen number are as follows for $l/L \leq 0.01$ the flow can be dealt with by the method of gas dynamics for $l/L \approx 1$ the behavior is termed slip flow for $l/L \geqq 10$ the behavior is termed free molecular flow or rarified gas dynamics [F H R]

Koala

An arboreal marsupial *Phascolarctos cinereus* found in the eucalyptus forests of Australia It is sometimes called the native bear koala bear or teddy bear and along with the kangaroo has become a symbol of Australia It is gray above shading to yellowish below The adult is about 3 ft long It breeds only every other year and the single offspring rides on its mother's back until it is about a year old As in other marsupials the young are born after a short gestation period are quite



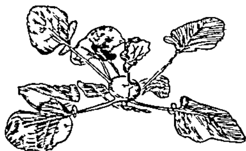
K l (F m E L P lm F ldb k f N l l H s-l ry McG -H ll 1949)

sm ll a d h lple nd mpl te the de lop- m t n abd m n l p h Th food f the k ala m d pent ly f th l f r s pecie f c lypt t e S e EUCALYPTUS MARSUPIA LIA

[J D B]

Kohlrabi

A cool e o b en t l c u f r (B a ul p a d B l a a l p) of n rthern Eu p an r g b l g n t th pla t d P p l K hl b g wn f r t t n pl k e l ged t m h h u lly ate k d g t bl K hl b G rm n w d m ng bb g t rnip nd r flect t m la ity n ta te d ppear e t both get ble C lt l p a t ces f k hlr bi simil r t th s d fo turn ps. Wh t V e a d P pl V e r pop l t H t g whe th l ged t m 2 3 d am te u lly 2 m th



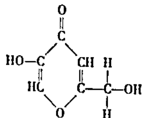
K hl bi (F m L H B l y d Th St d d Cy lo-pedia f H rtic lt l 2 M m ll 1937)

after plant ng A comm n cooked egetal le in Eu rope e pecially Germany kohlrabi i of min r im p tance in the United States *See* CABBAGE PA PAVERALES TURNIP VEGETABLE GROWI G

[H J C.]

Kojic acid

An rga c a d 5 hydr y 2 hydroxymethyl y pyro wh h has been pr duced n an experi me tal b sis by fermentat n There at p e e t n ind trial u f r k jic a id The compo d ha the f llow g t ct ral f rmula

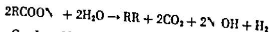


Sever l spe ies of fil me to f ngi of the genu *Asp gillus* c n produce th n ncarb xyli ri g type c d f m a i c rbohydr tes Sel cted tra bel gi g t the *A p g llus fl t s o y* g p g th h gh t weght y ld prod i g 50–65% of gl c e til ed A medium c nt n ng mi eral s lt and 10–25% c mme cial gl c e i adju t d t pH 1 8–2 0 The pH of the med um i e tic l Th med m n ocul ted with p e r my el m of the m ld nd c t u ly ae ated a d g tated nd ubme ged ndit for 5 days Th g i m l pr d es good yield n the sl wer u fa e t ay p oces Prod ct on f koji c d f ll wed q a t t t ly by the red c l r it gi s with f r c hl r de *Se* INDUSTRIAL MICRO-BIOLOGY

[J W F]

Kolbe hydrocarbon synthesis

The pr d ti n f n alkan by th el ctr lys s of a wat l ble alt f arboxyli c d The c r b yl t i s r d h ged at th node y eld g a bo d de nd lkyl ad cal wh ch c uple t f rm the tu ated hyd c rbo Hydr gen i lib- t d t the th d



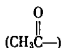
$$2RCOONa + 2H_2O \rightarrow RR + 2CO_2 + 2NaOH + H_2$$

Good y ld f lk es r obta ned w th th t aight ch a d nt n ng 5–18 c rbon t ms. Alke r the than lk nes a f rmed f the ac d c nta a lkyl b n h t the c rbo t m dj e t t the a b yl gr up th t s t th α p sti n f th a d S ALKANE

[L.S]

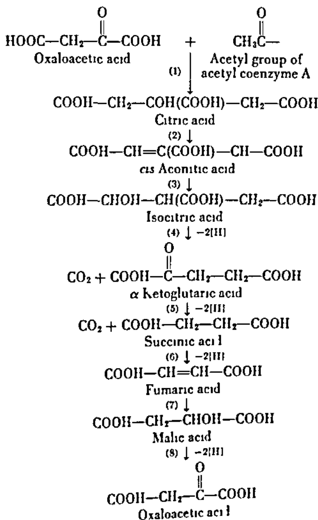
Krebs cycle

A eq n of nzymati e tio th t n l ed n th o d t m t bol m f m ny rgan m e p lly th th t carry t r p at on Th y l i al k wn th t d cy le d the t c b xyl d y le Thr gh th s que o p thway th two-c bo etyl t



an important metabolic intermediate derived from a variety of substrates can be oxidized to two molecules of CO_2 In aerobic metabolism two molecules of oxygen are u ed for this oxidation Organic acids containing four five and six carbons are formed in the course of the oxidation These are consumed and regenerated continually through the operation of the entire sequence Hence this oxidative pathway is a catalytic mechanism which operates in a cyclic manner and is known as the citric acid cycle because this tricarboxylic acid is one of the metabolic intermediates The cycle is also named after H A Krebs who recognized its functional role *See* METABOLISM

There are four oxidative steps in the cycle In each of the e two atoms of hydrogen or two protons and two electrons are removed from the substrate In aerobic respiration the electrons are transferred to molecular oxygen through the cytochrome system of iron porphyrin enzymes Energy rich phosphate bonds in the form of adenosinetriphosphate (ATP) are generated in the course of electron transport which therefore serves as the major source of energy for cellular metabolism Beside serving as a means for the complete or terminal oxidation of organic substrates which can be converted to acetyl fragments the reactions of the



Krebs cycle are used by the organism for the bio synthesis of important cell constituents which ca be derived from the metabolic intermediates partic ipating in the cycle The principal reactions of th Krebs cycle which will be discus ed below are out lined in the following diagram in which the oxida tive steps (dehydrogenations) are indicated by th symbol $-2[H]$

(1) The acetyl group which may be deri e from pyruvic acid or from other metabolic inter *mediates or substrates* enters into the cycle a acetyl coenzyme A (acetyl CoA) The so-calle condensing enzyme catalyzes the tran fer of th acetyl group to the four carbon compound oxalo acetic acid with the formation of the ix carbon tricarboxylic acid citric acid and the liberation of CoA

(2) and (3) Citric acid is dehydrated to cis aconitic acid which is then rehydrated to i ocitri acid Both the e reactions are catalyzed by th enzyme aconitase

(4) Isocitric acid is next oxidatively decarbox ylated to yield CO and the five carbon compound α ketoglutaric acid by enzyme sy tems known a isocitric dehydrogenases Depending on the bi logical source of the enzyme either diphosphopyri dine nucleotide (*DPN*) or *triphosphopyridin* nucleotide (TPN) may act as the coenzyme and immediate hydrogen acceptor for this reaction There is evidence that an unstable intermediate oxalosuccinic acid is formed in the cour e of the reaction

(5) α Ketoglutaric acid is then oxidized and de carboxylated to yield the four carbon compound succinic acid This involves a equence of reac tions in which DPN serves a the hydrogen acceptor and inorganic phosphate is taken up with the for mation of ATP from adenosinedipho phate (ADP) The first tep catalyzed by the α ketoglutaric de hydrogenase system requires DPN and CoA The products are CO_2 reduced DPN (DPNH) and succinyl CoA In the next tep the P enzyme de compo es the succinyl *C A with the* imultaneou formation of ATP from inorganic pho phate and ADP Succinic acid is produced and CoA i re generated

(6) and (7) Succinic acid is next oxidized to fumaric acid by the enzyme succinic dehydrogena e and fumaric acid is hydrated to malic acid by fumarase

(8) Malic acid is oxidized to oxal acetic acid b the enzyme malic dehydrogena e with the c ncom itant reduction of DPN Th i xal acetic acid i regenerated through the entire equence of reac tions of tl e cycle and l ecome a ailal le for re acting witl acetyl CoA

The enzymati reacti ns of the Krel cycle are imp rtant not only as a s urce of energy f r li ing cell b t al o as a so irce of e ential metabolic intermediate which er e a starting material f r li yntl etic proce e Thu α ketoglutaric acid l e me aminat d to yield tl e cl l glutamic

a id This compound in turn tak p rt in the s thes f ther amin ac d Oxal acetic acid on erted to a parti a id whi h is al o a pre ursor f a numb of am o acids a well as of pyrim d es Some of th i te mediates of the kr b cycl ar ex reted by the cell Citr c ac d f e ampl pp a s i the body fluid of an als and, und m cond t on is a m jor product of th met bol sm l molds Sim larly α ketoglutar c f m c, a d succinic cid are excreted by some mic oo gan m

Becau e the r mo al f the int med ate in the kr bs ycl through b osynthes s o excretion de str ys th i tegrity of the cycl as a catalytic mecha i m f th o idatio of acetyl unit li ing r m mu t p ss au il ry mech ni ms f r p n h ng th r upply of uch inte med tes so that oxal a eti a d can b e n ta tly ava l bl f the re t n One uch mechani m s th addi tion of arbon d ox d t pyruv c cid w th the oxid t n f reduced tr phosphopyrid ne nu leotide (TPNH) Th s ea t on which y elds m l ac d is catalyzed by th m l c zym O aloacet c a id c be y the ed from pho phoenolpyruvic a id a d CO in th pre n of inos ediph phat by a differe t nzyme A th r mp tant mea of thesiz g f u -ca bon d carboxylic cid a seq ene of actu n n which isocitric cid s split to u n c and gly xyl c a id nd th l tte c mp u d a ts with ac tyl C A t y eld mal a d A a e eque c of the a ti n two m l ules of fo -carbon c d n be prod ed with the on mpt n of n m lec l f xalo- n d nd tw m lecul f cetyl CoA S e AD NO INE IPHOSPHATE (ADP) ADE OSINETRI PHO PHATE (ATP) CELL (BIOLOGICAL) Co- E ZYME CYTOCHRO E DIPHO PH PYRIDINE NUCLEOTIDE (DPN) ENZYME PORPHYRIN TRIPHOSPHOPYRI I E NUCLEOTIDE (TPN) [M D]

Kronig Penney model

An de ed e-dimen on l model of ry t l hich exh b t m y of the ba f atu es f the ectronic s u tu of e l ry tal Co der the pot t al ene gy V (x) f n elect ll t ated Fig 1 w th n nfin t equ e f pot t l w ll l d pth −V a d width arr nged with p i g b Th Sch od g r w equ t n an be r ad ly sol ed f s ch a arr ngeme t t gi e el ct o e gy a fu ti f w mbe

The e ergy b d th bt ned with a c rta n h of tt nt h wn F g 2. The Kr nig P ney mod l h b en xt ded t l d th f

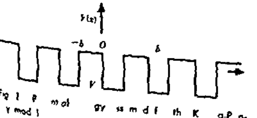
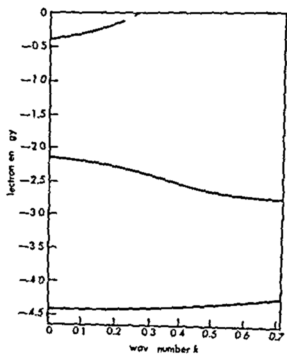


Fig 1 P m al gy ss m d f th K g-P n- y mod l



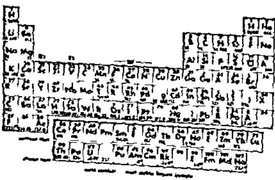
F g E gy a f nct f w n mb k for th K g-P ey mod l

fe ts f mpur t atom A solut on an al be de ri ed from the D a equ t on See BAND THEORY OF SOLID QUANTUM THEORY NONRELATIVISTIC. [J C]

Bibl g phy R d L. Kr ig and W G P n ney Qu ntum m cha es f electrons in ry tal latti es P Roy So (London) A 130 499-513 1931 R D Wood and J Callaway Relat i stic K n g P ney Mod l ONP Tech Rept 5 19

Krypton

Ch m cal el ment numb 36 krypton Kr is a m mbe f the fam ly of obl ga s gr up 0 f th period c tabl See INERT GASES



Uses Th pr n p l f r krypt n i fill ng lectric lamp and ele tr n c dev es of arious types Krypt rg n m ture ar w dely used to fill fl es ent l mp

Th h gh th m le l w ght of th t g s u ed t fill t ng-t n filam t l mp bulbs th less th t nden y f th tung t n t evapo ate wh n

heated thus krypton is a better filling gas al though more expensive than argon Two different uses are made of this advantage krypton filled lamps can be operated either at the ame bright ness as those filled with argon in which ca e the life of the lamp is a good deal longer or at higher filament temperatures to give a brighter light at greater efficiency (more lumens per watt) but this reduces the life of the lamp somewhat An example of a use for the brighter lamp is in lide projectors and projectors for home movies

Krypton is also used to fill electric arc lamps An example is a new lamp the light from which will pierce fog for 1000 ft or more Lamps of this type are arranged in rows to mark airplane run ways at night The lamps flash 40 times per minute each flash lasting only 17 μsec in order not to blind the pilots

Radioactive krypton 85 is relatively inexpensive and is finding a number of uses One is in leak testing of sealed containers Another is in the con tinuous measurements of the thicknes es of ma terial such as sheets of metal and pla tics An other u e is in lamp which give off light for several years with no source of energy other than the radio activity of the krypton in the e the invi ible radia tion from the krypton activates a pho phor coated on the inner glass walls of the lamp and the phos phor gives off light continuously until the krypton has decayed to a low level of radioactivity Kryp ton 85 can be used to detect abnormal heart open ings the introduction of this gas into the human body is practical because the krypton remains in the body for only a hort time working it way out via the blood stream and lung and i not fixed in the body

Occurrence The only commercial ource of stable krypton is the air although trace of krypton are found in minerals and meteorites Krypton con stitute 1 14 parts per million (ppm) by volume of the earth s atmo phere and this krypton is almo t entirely a mixture of the following i otope none of which is radioactive 78 (0 35%) 80 (2 27%) 82 (11 56%) 83 (11 55%) 84 (56 90%) 86 (17 37%) The relative abundances of the i otope is gi en in parenthe es after the ma numl er Since ome radioactive krypton 85 is formed when atomic bomb are exploded the air now contain thi i otope and krypton recently eparated fr m air i very slightly radioacti e

A mixture of stable and radioacti e i otope of krypton i produced in nuclear react r by the l w neutron fi i n of uranium

It i e timated that about 2 × 10 % of th weight of the earth i krypton Krypton al oc ur out ide the earth the le t e timat i that th r are al ut 51 at m of krypton for each 1 000 000 atom of the n in the i d le um er

Discovery Krypton wa di ov re l in Engl n l in 1898 by Sir William Ram ay and M W Tra ers they found it in the le s latile part of the inert gas mixture left after the oxygen and nitr gen ha l been remo ed chemically fr m a sample f air Th

Table 1 Physical properties of krypton

At mic n mbe	36
Atom w gl t (atmo pl krypt n only)	83 80
Melti g po t C	1
Bo l g p nt at 1 atm pres C	1 34
G s le ity t 0 C l l tm p es e g/l t r	3 t
Liq d l ty t its bo l ng po t g/ml	4
Sol l l ty i w t ml g p 1000 g w ter at 25 C l 1 tm p u	8 5

fact that a new element was pre ent was a cer tained by the di covery of new lines in the emi i n pectrum of the re idual ga

Properties Krypton is a colorle od rle and tasteless gas Table 1 gives ome phy ical proper ties of krypton

Krypton does not form chemical compound in the ordinary sense of the word although it f rm ome weakly bonded clathrate for example with water hydroquinone or phenol (see CLATHRATE COMPOUNDS) There is only one atom in each mole cule of krypton

Production Stable kryp ton i produce l in air eparation plant Air i liquefied and di tilled krypton and xenon remain with the oxygen Th liquid oxygen is redistilled to concentrate the kryp ton and xenon from a few part per million to a few per cent The rare gases are then ad orl ed from the liquid oxygen onto ilica gel de orl ed eparated and purified Final purification i carrie l out by pa ing the krypton over hot titanium metal on which all except inert ga impuritie are remo ed

A mixture of tal le and radioacti e krypton i otopes i produced in nuclear reactor The only radioactive i otope in the mixture which ha a half life of over about 3 hour i krypton 85 thi iso tope ha a half life of al out 10 year Thi wh n krypton from a nuclear reactor has l een t red f r e eral day the only radi active i otope left i krypton 85 Tal le 2 give the appr ximate i otopi compo ition of the krypton thu pr duced The comp iti n of the krypt n mixture varie ome what with c ndition in the reactor A nu lear re actor come into wide u e for power pr l i tion a large am unt of radi active kryp t n will l come availal le Since no cheap meth l of eparating the radi a tive fr m the table i tope of krypton i known tl n i lear r a tor i not at pre ent a source f tal le krypton e en th ugh al ut 9 % of the krypt n produce l in it c n i t of stabl i otope

Analytical methods The principal m dern meth d f d t cting an l quantitatively let rmin ing the krypt n ntent in ga e are ma spec tr metry an l ga chr matography Until these

T ble 2 Isotopes in reactor produc d krypton

M	be	I t g f y l m	
		St ll	R l l
8 80 8		1 3	
83		13 14	
84		) 33	
8			(
86		16 0	

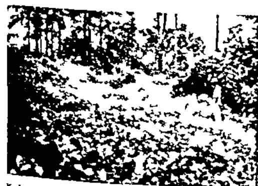
m thod ere devel ped it wa ec ary t s p rat krypt f m ther g es by lect e low t mp t d pt on on act ted ca b n i rd t d t rm ne h w m h krypt w s pre t a mixt e Th older method f detect g kryp t makes use f ts cha a t i tic m ion p trum btai ed by pa g gas mple th gh an lect d sch ge t b at low pre es and a lvz g the light w th a p ctr mete *S* ATMOS PHERIC G SE PRODUCTION OF [C A C]

B bliog phy F P Cro Jr R e ga es ev ryd y e *J Ch m Ed* 18 533–539 1941 R F Ki k d D F Othmer (ed) *E cycl ped a of Ch m cal Tech logy* I 7 1951 F J M izg T a es of (ra e g ses) f m t *I d E g Chem* 27 112 116 1935

Kudzu

A arm seaso pe e ial leg me with l ng p e d ing stem a d enl ged oot a d w th t ff b wn h r cov ring th y u g stem a d the trif l te l a es. K d g wn n well-dra ed o l n the south tern p rt f the U ted St tes It p d ces mod t y ld of good f g b t i ea ly k lled by ove grazi

Kudzu est bl hed by tr pl t t f 500–1000 pl t per Th tem of the pla t p e d g p dly d ti g t the d p o- d a f ll t d abo t 3 y The p i the dy t u f h y r grazing



K d d t bo d d ood

K d f the m t f l pl nt f p od g a bl k t of gr wth ev r ly e od d ea nd n t p dcut A f w w ll f rtil d pla t e t bl hed l g th b d f h d p t ted f m w ds w ll p d e d g d c n 3–5 y H we e gr wth ft p gres t ea hey d th f u ful nd t l d ffi lt

B gi g bo t 1938 ext pl t ng f kudzu we m d th S uthe t b t d l ha oc ed n 1948 *S* LEGUM E OR GES [P T]

Kumquat

M mbe f th g u *F tu ll* wh h o f th x g n ra in th gr up f t t f t Th kumqu t a b l eved t h g ted



F t l t f N g mi k mq t (*F rt ll m g t*) (*U H c M F I d C*)

Chi and the M lay P i ila b t are n w w del gr wn in ll citru are f th wo ld There ar everal p cies the mo t omm n l e g *F m g rita* wh ch has o al haped f uit a d *F j p nica* wh ch ha r nd f it

Th k mq t ar hrub r m ll tree the r tems lea es fl wer nd f uit r ml le *Cit u* K mq at b r umer u fl m t a g -colo ed f u t f m ll e ft n l th l in i d ame- t r ha ng 3–5 l i les fill d with n ac d pulp a d we t ed ble p lpy r d Th tree r am ng the m t c ld h dy f th tr fr t nd tav d rm t ev d r g p tra ted w rm pell in the wi t r mo th wh ch nables th m t w th t nd low temp at

Th kumquats with th r br ll t r ge-c l ed f t d d n e g e f liag r h ghly ornam n t l a d a m t fr q e tly gr wn fo th ea Sp ay f f li g a d f it e c mm ly u d f r de r tion p t ul ly i gift package of rd n ry tr f u t Th k mq at f t an be eate wh le w th t p li g d a e l o used in marm l d d p e rve nd c ded f u ts Th i ult the U ted Stat s a rel t ely sm ll cale *S* FRUIT (TREE) [F E C]

Kutnahorite

A c b t f c l m a d mang es C M (CO) K tn h t ne e f nd in na t r witho t me m gne m d ub titut g f m g es I t g t o f m n al sy the how ompl t l d luti b tw en al it a d k tn h it t somewhat l t d temp ra tu e

K tnah te h h g l (rh mbohed al) sym m try d the m t uct e d l mite It p k c l d h p fi gra ty of 3 It i f nd Czech l ak a Sw d a d t F nkl N w J r y *S* CARBO ATE I ERALS [R I H]

B bl g phy J R Gold mith and D L Graf The y t m C O-M O CO l d l t n d d

composition relations *Geochim et Cosmochim Acta* 11 310–334 1957

Kyanite

A nesosilicate mineral composition Al_2SiO_5 crys tallizing in the triclinic system Crystals are usu ally long and tabular and commonly occur in bladed aggregate There is one perfect cleavage the specific gravity is 3 56–3 66 The hardness of kyanite one of its interesting features is 5 (Mohs scale) parallel to the length of the crystals but 7 acro s the length

The luster is vitreous to pearly and the color is usually a shade of blue but may be white gray or green *See* SILICATE MINERALS

Kyanite is a polymorphic form of Al_2SiO_5 the other forms being andalusite and illimanite These three minerals are found in aluminous metamorphic rocks each stable under different condition Kya nite is formed at low temperature and high pres sure relative to andalusite and sillimanite The transitions from one mineral to another are so sluggish that they may coexist in the same rock *See* ANDALUSITE SILLIMANITE

Kyanite is characteristically found in mica schists often associated with garnet staurolite and corundum Fine crystals some of gem quality are found at St Gothard Switzerland Kyanite has been mined in India and in the United States in Georgia and North Carolina for the manufacture of highly refractory porcelain [C S H C]

Labradorite

A plag cl e feldspa w th a omposition ranging from $Ab_{50}An_{50}$ to $Ab_{30}An_{70}$ ($Ab = NaAlSi_3O_8$ and $An = CaAl_2Si_2O_8$). I the high temperature tate l b dorite h alb te-type struct re In the co r e f cooling n tu al mater al d vel p pecul a structu l tate hi h whe i ve tigat d by x ay h s flecti n th t i dicate the beginn ng of an e sol ti n pr s s met me accompan ed by a b t f l r ou ly olored l ste (lab adorizing) *Se* FELDSPAR IGNEOUS ROCKS [F LA]

Labyrinthodontia

An import t gr p of f il amph bi ns de sce ded from c o s pteryg an fi hes a ce tral t ptiles and pr bably ant ced nt t part if not all the o he amph b an types The labyri th donts ranged i time f om Late Dev nia to Late T ia s c and i cl d d all the l rger nc ent amphib ans a d as a variety of sm ller types The labyr nth od nts w e chara teri ed by the apsido p d lo s rt bral c tra with di ti ct interce tra and pleu roc ntr of n ble c n tru t o Earlie t f l by rinth dont wer the Ichthy tegalia of the Upp r Devon they were succ eded by the Rha hitomi domina t in th C b n f o s and Permia which t s ce ded n tu n by the T emat a ia and St eo pondyl n the Tri s c In th e f ur gro p cl s ed a T mn p ndyl the pl u c n tra we e small nd s m t m s ab e t l a d ed gr p the A th a au fo nd i th Ca bo f d P m a th ple o entr had e p ded mpl t g cl ded re the Embol meri nd f rm le ding to th S ym u amorph and th ept le *S* AMPHIBI FOSSILS E TEOLO MERI ICH H OSTEGALIA RHACHITOMI STEREO SPO DYLI [A S]

Labyrinthulales

A little t d d gro p of m g m f un t m l t h ps They a e g lly gard d s l m m ld nd lo g w th the pla m d um f m g My g t l th p ud pl m d um f rm g A r les d th phyt p thoge Pl mod o ph ta f th b t t th My et z d of the zool g Th r l ttle t ugge t cl e affin ty t s y ne f th g up nd gnm nt w th th m l g ly a m tt f o en n b a th y fit o th r k w gr up f pl nts or a mal All aqua c a d m t a m e f rm that grow n in ssoci t w th m y typ of lg e d other marine pl nts Their ability to para it ze dia t ms has been clearly demon trated and they are gene ally regarded a the pathog ns resp n ible f r the o- alled wa ting di ea e that alm t ob- l terated the eelgra (*Zo t a m rina*) fr m tl e hallow water along th Atl nt c eaboard be- tween 1931 and 1940 *See* ACRASIALES MYCETO- ZOIDA

The egetat e cells of *L by nthul* the nl g nus pre ently ec g z d are typ cally f i iform n h pe nd mo e by a curi s glid ng m t on up n a netw k of slime t ack that tl ey them l es *pro-* du Th netw rk f ana tomo ng path and mo ing ells was r ferred to a a net pla mod m by early invest gators and more th n any ther fea ture of the r de elopme tal cycle th unique tage cha act rizes the genus *Labyri thula* The egeta ti e cells are not amebo d i a t e n e alth ough they ha e been so reported and do in f ct show *re* markable pla ti ity *as they glide past* one another o mo e ar nd ina im te objects encou tered in *their path They are* not nourished by the engulf ment f bacteria or other particulate food hut by the uptake of nutrients in solution or those that th y s lubilize by extracellular enzymes as when growing par itic lly upon d atoms or other liv g ell Reproducti n occ rs by *transver e or longi* tud nal d i n f the f ifo m cell *following* a pri r m t ti d i n of the *nucle s* A flagellate tag *has bee* obs rved upon rare o ca on but its gn fi ance in the l fe cy le rema s b c r

Spec es of L byri thula an be readily culti ated n the l borat y up n a s ft agar medium c n t ng of fresh s a w ter en h d w th 10% blood ert m as epo ted by S W Wat n and E. J O d l [K B R]

B bl g phy S W W ts n and E J Ordal T chn q e f the i lat n f *Laby thula* a d *Thr u tochytrium* in p e c lt re *J B cteri l* 73 589-590 1957

Laccolith

A geologi nam f body f gneou rock in t ud d i t d me tary r ck su h a w y that the e ly ng trata ha e bee ot bly l fted by *the f c f* ntru I th m st simple ex mpl the l c l th c c la r al pla the ubj nt ed *ment ry* k nd *the floo of* the la co- l th r n ly h r z nt l d the oof i d me- ha ed w th th sed m ntary ro ks a h g o er the d *me* Type xampl in th H ry Mounta n Ut h (de c b d by G K Gilbert in 1877) a d m ny upp d ex mple sub equ ntly d cribed

in the western United States have been shown by more detailed work to be much more complex than originally de cribed *See* PLUTON [J A N]

Lacquer

A surface coating the vehicle of which contain a substantial quantity of a cellulose derivative This derivative is most commonly nitrocellulo e but may be a cellulose ester such as cellulose acetate or cellulose butyrate or a cellulose ether such as ethyl cellulose The term is ometimes used for other coatings which have properties and uses simi lar to those of lacquers particularly clear metallic coatings Originally lacquers were coatings pro duced by the u e of the juice of a tree of the sumac family but these materials often called Oriental or Chinese lacquers are not widely used today

Lacquers are made by dis olving nitrocellulo e and other modifying materials in a solvent and pigmenting if desired They dry by evaporation of the solvent Becau e solvents with very high vola tility may be u ed extremely fast drying times may be obtained and lacquers are usually applied by spray The drying time may be extended to al low brushing but bru hing lacquers are not com monly used

Nitrocellulose is not oluble in conventional paint thinners so that a mixture of solvents usually containing esters (ethyl acetate) aromatic hydro carbons (toluene) and petroleum thinners are used Alcohols and other olvents may be pre ent The olvents must be chosen carefully for the com bination of solvency and evaporation rate required

Nitrocellulose is very hard its flexibility is mod ified by the addition of plasticizers These may be *vegetable oils such as castor or lin eed which have* been modified to l e compatible with nitrocellulo e or chemical compounds such as dibutyl phthalate or tricresyl phosphate Numerous other materials are also used for this purpose The adhesion of lacquers can be impro ed by the addition of other resins and the e also may reduce the co t by allow ing the use of le s expen ive olvents or alterna tively allowing the application of heavier film

Hi torically the de elopment of lacquer came in the early 1920 when ample supplies of rela tively inexpensive chemical solvents l ecame avail able after World War I This coincided with the great increase in the production of automobiles and the demand for a fa t drying weather resi tant fini h which could be u ed to replace the previou ly used enamel which required l ng drying peri d Lacquers till con titute the fini h u ed on about one half the *automol iles produced in* the United States and furnish a ul tantial portion of the coating for furniture and other factory fini l ed items

Lacquers using other cellul e derivative are much le common Cellulo e acetate acetate bu tyrate and butyrate have certain specif c u es par ticularly for clear coatings where good weather resi tance i required Ethyl cellulo e gi e film *of extreme flexibility but such coating* are too soft for many u e *See* PAINT SOLVENT SURFACE COATING [F B]

Lacrimal gland

A tubuloalveolar or acinous kin gland al o known as the tear gland The lacrimal glands devel p from the skin epithelium which fold inward o er the developing eye Two types occur among the vertebrates the lacrimal proper and the Harderian The e eye glands are first found in the amphibians associated with the in ide of the lower eyelid In urodele amphibians the eye gland extends along the inner aspect of the lower eyelid In *Salamandra* it becomes divisible into an anterior Harderian gland as ociated with lower eyelid tructures and a pos terior lacrimal gland below the upper eyelid In frogs and toads only the Harderian gland is present and is associated with the nictitating membrane or third eyelid which develops in relation to the lower lid

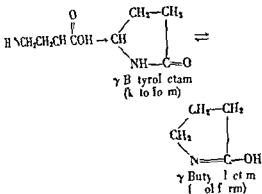
The eye glands drain into the na al cavity by means of the lacrimal duct In higher vertebrates with the exception of nakes certain lizards and geckos Harderian and lacrimal glands are pre ent In the higher vertebrates the Harderian gland func *tions in relation to the third* eyelid or nictitating membrane and the lacrimal gland become lo cated dorsally above the eyeball near the outer angle of the palpebral fi sure In aquatic mam mals such as eals whale and sea co the Harderian gland is the more prominent of the t o ets of eye glands and it ecrete a ebaceou or oily substance In land mammal the lacrimal gland proper is highly developed as a complex tubulo *alveolar tructure with everal ducts* which pour their copious fluid into the outer upper part of the conjunctival ac or cavity The tear ul *tan e* wa hes acros the eyeball to the inner palpebral fissure or commis ure Fventually it pas e through two mall opening one on the margin of each lid into the lacrimal duct The latter converge to form the lacrimal sac from which the na lacrimal duct lead into the na al pa ageway Tear conta n *a considerable quantity of the common* salt so dium chloride *See* FPITHFLIUM FYE FYF DIS ORDERS GLAND [O F]

Lactam and lactim

Lactams are internal (cyclic) ami le f rmed b heating γ and δ amino acid structurally they are nitr gen analog of the corre ponding γ and δ lactone Thu γ aminol utyric acid readily *form* γ l utyr la *tam omm* nly known a pyr rolidone

Tl e formulas how lactim to be tat t meric en l form of lactams with whi h they f rm an equil b rium wl e er the lactam nitr gen carrie a free hy lrogen

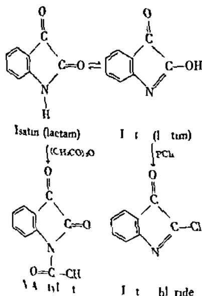
Pyrr li lone ha weakly a i li an l l a c pr per tie forming a l ydr hlori l an l a sodi im salt Alkylation of th latter gi e N alkyl pyrr li l nes



Wth a etyl ne *N* inylpyrrol d e f m poly me g t p lyv ylpy r lid ne the latt r i u ed i aer sol p y fo hai tt g

Comm r al p d ti l pyrr l done ut l e ether tr atm nt f γ b ty la to e w th mmon the p rt l r d ct n of su ci m de P p r d ne (δ l l ct m) i m d f om δ al ol ct e and mm Sm ller r g (β l t ms) and la ge (d h ghe) m t be made b nd re t method h dd ti n of kete es t im es f β l ct m d g xpa i n a B ckma n re rr ng m t f cycl k t xime fo a d higher l t ms.

Th ta t me qu l br m x t g between la t m d l t m t ctu e i w ll e mpl fied i at n n dau n p od t of i dig



Th t a th l t m t w th t c an h d d t f m N tyl at w th ph ph u p t hl d t e t a th l t m g g t hl d

Alth gh γ d δ m c d e nt i themsel es th r p d g la t m sh w p o- ed t h t p t ty *S e* A INO ACID L CTI A D LACT NE [E B R]

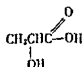
Lactase

An enzyme found n mammal h eybee larv a d me plant It i a β gala t ida e wl ch l y d l z la t e t ι l ct e and gl In mam mals la t e app r in the i te ti al s cr ti n that i fr m the i testi al villi a d e erts its effect o la t e in chyme *See* E ZYME GLUCOSE.

[D N L]

Lactate

A alt re ter f la tic cid



in wh ch the ac d hydrogen has b en replaced l y m tal o a orga ic rad cal Alkali metal alt ar w ter l ble th rs ar in l ble Ma y alt h pr ct al applicat n f r ampl a l lood gul nt n calc m theraj y (alci m) a a tip p r t (lum um) in tr atment f a e m a (i n) and a pl t ci r (d m) Lower m lec lar w ight t s ar water l il l E te u d a ol ents f lacquer cell l e c tate and cell l e ntrat *S e* CARBOXYLIC ACID ESTER LACTIC ACID SOLVENT [E H H]

Lactation

The f n tio al a t tv f th m mm ry gla d whi h the e eti n f m lk

Soo aft r birth the you g b g n p iod nurs- r m lk rem l A ery mport nt mechani m n l g both the ervou and docr ne y tem m i to pl y Th a t f n r i g s nd nerve im pul t th b and p te i p t itary whi h th d h rg f oxyto n i t the l lood Th s h rm e fl t th m mmary glands cau g th o t a t o f m ep thel al c ll whi h urr nd e h l l f i g th m lk f m the l me f the l ol nt the d t f r rem al by the n l If th m th r i d ti bed t th time f r g hormo e dren l n is d charg d f m the adr l gla d If ad nal aches the m mma y gland bef yt c s di charg d it p e t th e nt a t n of th myo p th l m a d m lk m al d s n t t ke pl e Th n sing m th m t b nt ted a d fre of t e r citeme t

Milk production The fi t milk c l trum s et d b f re pa tur ti t p i lly r h in g mm gl bul wh ch c t n imm ne bodi Th d gest t t f th n wb rn b b th s p t nta t nt the blo d th nf a tempo- ry mm ity t mm n d a e W th the regu l r m l of m lk th am nt f m lk s ret d n r fo a per d of t me then gradu lly d l e u t l th mal a d t dry up I d ry a m l h the w p gnan y i duced b t th t th d y (th l ctat n p i d La

tation and pregnancy with additional growth of the mammary glands occurs so that a second lactation period is initiated at yearly intervals The total yield of milk increases each year until about the seventh or eighth year then declines with old age

Control of secretion The secretion of milk is under hormonal control At the time milk is removed by the mediation of oxytocin the nursing stimulus also causes a discharge of lactogenic hormone into the blood which stimulates milk manufacture during the interval between nursings Without this hormone the cells cease to secrete milk However there are a number of other hormones which influence the intensity of secretion Of these the growth hormone of the pituitary gland and thyroxin from the thyroid gland are most important The effectiveness of these hormones can be shown by their administration during the declining phase of lactation When thyroxin is injected or thyroprotein is fed to dairy cattle at this time there usually follows an increase in the yield of milk for a period On the other hand if the thyroid gland is removed lactation is reduced up to 40% An optimal level of thyroxin secretion is essential for optimal milk secretion The growth hormone which regulates body growth also plays an important role in regulating milk secretion *See* MAMMARY GLAND *see also* ADRENAL GLAND PITUITARY GLAND THYROID GLAND [C W T]

Lactic acid

A slightly hygroscopic syrup with a specific gravity of 1 294 at 25 C The acid also known as α hydroxypropionic acid contains one asymmetric carbon atom and exists as two optically active isomers that can be converted by an enzyme racemase into the racemic mixture (*see* OPTICAL ACTIVITY RACEMIZATION) L(+) lactic acid also called sarcolactic and paralactic acid is metabolized by animals whereas D(−) lactic acid is not The lactic acid of commerce is the racemic mixture commonly known as i lactic acid (optically inactive) Annually 5 000 000 lb is produced for use in pharmaceutical preparations in the textile and leather industry in the production of inks solvents lacquers and plastics and as a food preservative

Lactic acid may be prepared chemically although industrial production is by fermentation

Fermentation Industrial production of lactic acid is accomplished by fermentation of refined glucose hydrolyzed starch whey and molasses The more refined substrates are used for production of the higher grades to reduce purification costs Sulfite waste liquor juice of culled citrus fruits enzymatically hydrolyzed potatoes and acid hydrolyzed wood mill sawdust straw corncob extracted beet slices and Jerusalem artichokes have also been proposed as substrates

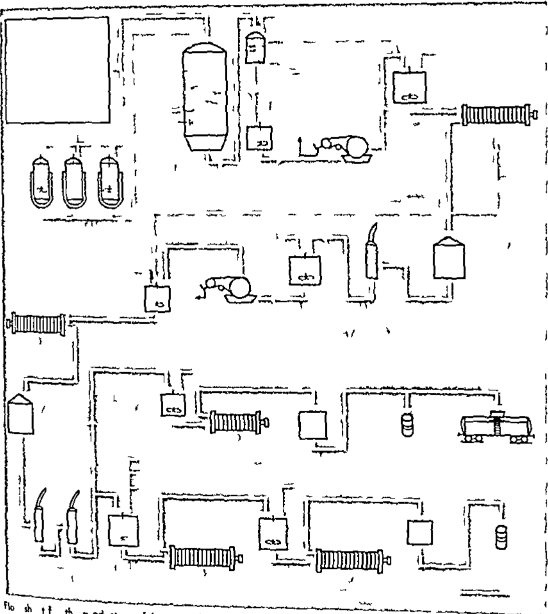
Bacteria suitable for commercial production of lactic acid may be isolated from souring foods grains malt sprouts or soil These organisms have complex nutritional requirements For example *Lactobacillus delbrueckii* requires 14 amino acid and 4 vitamins and is stimulated by a number of other substances These growth factors can be provided by adding small amounts of malt sprouts corn steep liquor distillers grains or solubles koji rice bran peanut oil cake soybean cake undenatured milk or extracts of liver and yeast Maintenance of the culture requires frequent transfers in media of low sugar content such as 5% corn mash

In one commercial process *Lactobacillus delbrueckii* is transferred serially from test tube to flasks to seed tanks and finally to the wooden or stainless steel fermentor maintaining an inoculum level of 10% Each transfer is made after 16–[illegible] hours of growth at 49 C which is assiduously controlled The medium consisting of 15% glucose 0 4% malt sprouts 0 25% diammonium phosphate and 10% calcium carbonate is not sterilized The industry relies on cleanliness the high temperature and low pH to restrict contaminants Butyric bacteria are the most troublesome particularly as they produce volatile acids in addition to a racemase Although the batch process is usually employed continuous processes have been devised Corrosion is a major problem

The fermentation requires four to six days when the concentration of sugar falls to 0 1% or less and the yield reaches 90–95% Small changes in pH adversely affect the fermentation and automatic control is advantageous The optimum pH of 5 6–5 8 is maintained by adding sufficient calcium carbonate initially or intermittently as required Although not used industrially the submerged cultu

Table 1 Characteristics of lactic acid organisms

Organism	Morphology	Substrates	Optimum temperature	Acid produced
Lactobacillus bulgaricus	Rod	Lactose whey	4 0 C	Racemic
Lactobacillus delbrueckii	Rod	Glucose molasses	4 0 C	L(+)
Lactobacillus brevis	Rod	Pentoses hydrolyzed wood	30 C	Racemic
Lactobacillus plantarum	Rod	Pentose sulfite liquor	30 C	Racemic
Streptococcus lactis	Coccus	Lactose whey	3 C	L(+)
Bacillus coagulans	Rod forms spores	Glucose l tose	4 0 C	L(+)
Rhizopus oryzae	M [illegible]	Glucose starch	30 C	L(+)



Flo sh t f th p od ct f l ct d

u ol *Rh pus y e t med* c tai g 13% gl ose g es 75% y eld f la t a d n 35 ho rs Th f rmentat h th d ad ntage of l we y ld nd q ng a ept c d ti but the ad nt g of p od g L l ct a d *r* a l r b th Reco ery f la t c d f m f rm nt d l q or r th d ffi ult bec e f th l w ap r p ur f lactic d nd t t d cy t f rm a hydr de d dr g ll est r fic t wh n heat d and co t ed bo 20% d l b a t olu bil ty m l r t w t Th imp rta t t m is e p ot *r* f me ted s g n gani lt and l ed m te r l The u ual p t ce t co g l t the p *r* d mplet ly e t l z th lactic d by he t g t 90 C w th e l m Th sol ble *m tt* is rem ed by filt t n f ed m t l a d l bl p t *by t e t* m nt *th* ha oal Th c l m l t te th

either c nc t at d a d p y d ied o c l d and llowed t cry tall La t c acid *pr pared by* treat g a olut n of calci m lactat with s lfur ac d nd filt ng ff th n l ble c l um ulfat The cid s th n r p t dly bleach d until the de r d pu ity atta ed S *m o g n* impurit s in l ct ac d c be de tr yed by tr atme t w th ox *d z g a t u h* hyp hlorit o tr c ac d

Alt rnat e methods p op s d f pu ify g l ct d i l d (1) team d till t on nder cuum (2) *cry t ll zati n* as th c o iline lt (3) e tra t n f th la t c c d with nitro-pa affin isop opyl *ether o* o myl alcoh l d (4) con e s n t n t r Th l tt r proce s has be c s f lly ppl d to the re y of methyl l t te f om f m ted p tato m he

Chemical production La t c d may be p e p d hem lly by (1) r acti g l hyd ox d

tation and pregnancy with additional growth of the mammary glands occurs o that a second lactation period is initiated at yearly intervals The total yield of milk increases each year until about the seventh or eighth year then declines with old age

Control of secretion The secretion of milk is under hormonal control At the time milk is re moved by the mediation of oxytocin the nursing stimulus also causes a discharge of lactogenic hor mone into the blood which stimulates milk manu facture during the interval between nursings With out this hormone the cells cease to secrete milk However there are a number of other hormones which influence the intensity of ecretion Of these the growth hormone of the pituitary gland and thyroxin from the thyroid gland are mo t impor tant The effectiveness of these hormones can be shown by their administration during the declining phase of lactation When thyroxin is injected or thyroprotein is fed to dairy cattle at this time there usually follows an increase in the yield of milk for a period On the other hand if the thyroid gland is removed lactation is reduced up to 40% An optimal level of thyroxin secretion is essential for optimal milk secretion The growth hormone which regulates body growth also plays an impor tant role in regulating milk secretion *See* MAMMARY GLAND *see also* ADRENAL GLAND PITUITARY GLAND THYROID GLAND [C W T]

Lactic acid

A slightly hygroscopic syrup with a specific gravity of 1 294 at 25 C The acid also known as α hy droxypropionic acid contains one asymmetric car bon atom and exists as two optically acti e isomers that can be converted by an enzyme racema e into the racemic mixture (*see* OPTICAL ACTIVITY RACEMIZATION) L(+) Lactic acid al o called sarco lactic and paralactic acid is metabolized by ani mals whereas D(−) lactic acid is not The lactic acid of commerce is the racemic mixture commonly known as ι lactic acid (optically inacti e) Annu ally 5 000 000 lb is produced for use in pharmaceu tical preparations in the textile and leather in dustry in the production of inks solvents lacquers and plastics and as a food preservative

Lactic acid may be prepared chemically although industrial production is by fermentation

Fermentation Industrial production of lactic acid is accomplished by fermentation of refined glucose hydrolyzed starch whey and mola ses The more refined substrates are u ed for produc tion of the higher grades to reduce purificati a costs Sulfite waste liquor juice of culled citr fruits enzymatically hydrolyzed potatoes and acid hydrolyzed wood mill sawdust straw corn obe extracted beet slices and Jerusalem artichokes have also been proposed as substrates

Bacteria suitable for commercial production of lactic acid may be isolated from ouring foods grains malt sprouts or soil The e organi ms have complex nutritional requirements For example *Lactobacillus delbrueckii* requires 14 amino acid and 4 vitamins and is stimulated by a number of other substances These growth factors can be pro vided by adding small amounts of malt prout corn steep liquor distillers grains or olubles koji rice bran peanut oil cake oybean cake un denatured milk or extracts of liver and yes t Maintenance of the culture requires frequent tran fers in media of low sugar content such as 5% corn mash

In one commercial process *Lactobacillus del brueckii* is transferred serially from te t tube to flask to seed tanks and finally to the wooden or stainless steel fermentor maintaining an inoculum level of 10% Each transfer is made after 16-? hours of growth at 49 C which is as iduously con trolled The medium consisting of 15% gluco e 0 4% malt sprouts 0 25% diammonium phosphate and 10% calcium carbonate is not sterilized The industry relies on cleanliness the high temperature and low pH to restrict contaminants Butyric bac teria are the most troublesome particularly as they produce volatile acids in addition to a racema e Although the batch proce s is u ually employed continuous processes have been devi ed Corro ion is a major problem

The fermentation requires four to six days when the concentration of sugar falls to 0 1% or le and the yield reaches 90–95% Small changes in pH ad er ely affect the fermentati n and automatic control i advantageous The optimum pH of 5 6– 5 8 is maintained by adding suff cient calcium car bonate initially or intermittently as required Al though n t u ed indu trially the sul merged cult

Table 1 Cha acteristics of lactic acid organisms

Organism	Mɾrpl ology	Sul t ates	Opt mu n t mper tu e	Acid prod ed
Lactobacillus bulgaricus	Rod	Lactose wl ey	45 0 C	Ra em c
Lactobacillus d lb ueck i	Rod	Glucose m l sses	4 50 C	L(+)
Laclobac llus b evis	Rod	P ntoses l ydr lyzed wood	30 C	Racemi
Lactobac llus plantarum	Rod	Pentoses ulf t l qu r	30 C	Racemi
Streptococcus lactis	Coccus	L tose whey	3 C	L(+)
Bacillus coag lans	Rod f r s pores	Gl cose l tose	4 0 C	ι(+)
Rhi opus ory ae	M ll	Glucose star l	30 C	ι(+)

a se f th x t g nutrit al eq re t S B OASSAY VITA IIN
h f m ly is d id d m ph l gic lly int e f phe cal l ghtly el ngated c ccu ms Streptococ e e d tr be f r d f rm tob c lle e (F 1)
Morphol gy rem ins th rel ble g d t cla t b t u t ble data a s anty Phy log al sct rs e th ref nd p ble even gh me t x m t prefer n t t u e s h ir ct f d ff re t ati b y d the pec es l
Streptococceae Th t b Strept co eae is di led t fi e g era b ed po m pl ol g c l d ph l g cal h ct The p c of f u thes *D ploc us St pto cus Le o t d P pt t ept s i l* de typic l ph ric l c f m h h d d n e pla e and u lly c p ir h rt ch s (F g 2) The fifth en *P d cc* l d pec wh h oft ccur tet d gr p g ne tati g d n in pl s (F g 3)
F f th g e a bt the r e gy by fe ment t f b hyd t r lated mp d Thes l d the p i f th g era *D pl o us* and *St ept* which p d dext t

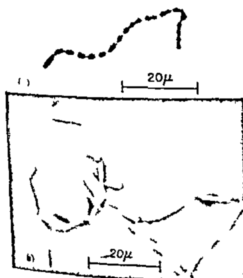


Fig 1 Morph logy f th tw t b f th L ct b cillaceae ph ograph ( ) St pt f l tribe S p ococ (b) L ct b ll b t b L ctobacilleo

l ct d pe of th g *P d us* h h p od a m m xt r of l t c a d d *Le to* p wh h p od d able mou t f c bon d de ethyl l h l a d tic a d m add t t lev t tory la t d Species f the fifth g u *P pt t ept cus* e er bic, ut liz p t -decompo t p d ts ll bob d tes d p od d th th lart d t

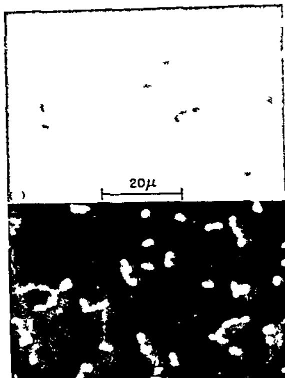


Fig 2 Ph t m g ph f L t m f d t b St pt ( ) E p l t d c ll (b) Ch d p d d gl ll

Th ge *D pl ccu* l des the pa a it c p i s *D p mo* ca t gent f l ba p m
Th g u *St pt c i s* i l d mer u par te a d p phyt The g d d d t fo phy l g l gr p py ge ic i idans te d l t In g l th fir t tw t f l w d pr d ng p s p e t i th l ment t t d fe ti Tl d two g p th l ghe d p d cing type a at d w th f me t t n f f d products S p t f p by ol g l m tl d rrel te w ll w th t mp t e g wth r ge alt t le d g wth milk S SEROLOGY STREPTOCOC S
Th g *L sto* i l d the hete of m t t p e ci t d w th f d They w

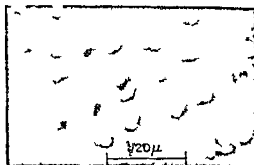


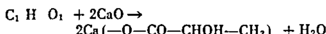
Fig 3 Ph t m g ph f t t d d p d ll

Table 2 Grades of lactic acid

	Tech cal	E I I I	Pl t c	USP
Tot l d ty	41%	50%	50%	85%
Volat l d	1 %	1– %	1–2%	–3%
A h	0 6–0 7%	0 1–0 5%	0 00 – 0 01%	0 05–0 1%
C bon able m tt	Present	P ent	Non	Non
Colo	B own	Pal y llow	Col les	C l less

with bromopropionic acid (2) oxidizing 1 2 propane diol with permanganate (3) deaminating alanine with nitrous acid (4) reducing pyruvic acid (5) combining acetaldehyde with carbon mon oxide at 200 C and 900 atm pressure (6) hydrolyzing acetaldehyde cyanohydrin and (7) degrading sugars with alkali These methods produce racemic lactic acid and being more expensive than the fermentation proce s are not widely employed D(–) Lactic acid may be prepared from methyl α D 6 deoxymannopyranoside and L(–) lactic acid from methyl α L 5 deoxyarabinofurano ide by oxidation with periodic acid and bromine in aqueous olution

Production of lactic acid by alkaline degradation of sugars according to the following equation is the subject of numerous patents



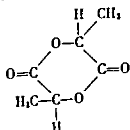
$$C_1 H O_1 + 2CaO \rightarrow 2Ca(-O-CO-CHOH-CH_3) + H_2O$$

In practice however the sugars undergo many other kinds of rearrangements fragmentation and oxidation The yield of lactate is therefore of the order of 50% of the theoretical In alkaline solutions sugars undergo rearrangement fragmentation and oxidation to various acids The yield of lactic acid depend on such factors as structure of the sugar concentration and type of alkali and temperature Sucro e i mo t efficiently degraded and aldonic acids are superior to aldo es When mola e i diluted to 18% sugar and treated with 13% calcium oxide for 2 hours at 230–235 C the yield of lactic acid is about 40–50% *See* CARBOXYLIC ACID [F J S]

Bibliography R Montgomery *The Chemical Production of Lactic Acid from Sugars* Sugar Re earch Foundation Sci Rept Ser 11 1949 S C Pre cott and C C Dunn *Industrial Microbiology* 3d ed 1959 L A Underkofler and R J Hickey (ed) *Industrial Fermentations* 1954

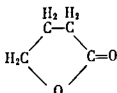
Lactide and lactone

Lactides are cyclic intermolecular d uble esters formed from α hydroxy acids Thus lactic acid CH CHOHCOOH on heating form a lactide



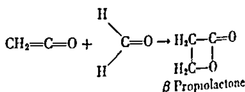
Glycollic acid HOCH COOH behaves anal gously In each ca e bimolecular interaction oc curs forming the strain free 6-membered r g Most lactides are relatively low melting solid and are easily hydrolyzed by ba e to form alts of the parent acid for example odium lactate

Lactones are internal cyclic mono e ters formed by γ or δ hydroxy acids pontaneou ly thus γ hydroxybutyric acid HOCH CH CH COOH forms γ butyrolactone



Other lactones of maller or greater ring ize are prepared specially

The γ and δ lactones are commonly prepared by either hydroly is or di tillation of γ or δ halo acids by treatment of un aturated acid with aq e ous hydrobromic or sulfuric acid or by partial reduction of cyclic acid anhydride β Lactones result from the reaction of ketene with aldehydes or ketones



β Propiolactone

Large ring lactones can be made by oxidati n o cyclic ketones with Caro s acid thus cyclohexa none yields caprolactone

The lower lactones are neutral liquids that reac with ba es (alkalie ammonia and amines) to gi open chain derivatives of the parent hydroxy acids Very large-ring (macrocyclic) lactone for exam ple 15 or 16 carbon have pronounced mu k od r (perfumes)

Unsaturated lactones (butenolides) are widel distributed for example the angelica lact nes penicillic acid and protoanemonine (mold metabo lite) coumarin (tonka bean) and dicoumarc (spoiled weet clover) u ed medicinally a a hem orrhaging or anticl tting agent in coronary thr m l o i *See* ESTER [E B R

Lactobacillaceae

A family of bacteria of the order Eubacteriales A th ugh they are primarily sapr phytic a few spe cie are path genic The bacteria are g nerall known a ugar fermenters producing lactic ac a a maj r produ t They are f und in f rmentin f d produ t in the m uth in the inte tinal trac and in l ly le i n Th saprophyte u ually ar n nm til and sh ow neither reducti n f nitrate gelatin liquefaction catala e producti n n r su fa e gr wth in li uid media The speci are mi croaer ph ilic or anaerob ic inacti e t ward pr te ources but f tidi u in th ei req uirement Som strain have bee m val l gical a a

bec e of th e ct g t ti nal req m ts S BIOASSAY VITA IIN

Th f mily d ded m ph l g ally into a tribe f ph l l ghtly elo g ted c c f rms, Streptococce a d t ibe f od f m La tob lleae (F g 1)

M ph l gy m s th rel ble g de t cl s fi ti b t t ble data are s anty Phy lo cal h a t th f d p bl n th gh some t m ts prefe n t t u h har ct f r d ff tiat b y d the spe e lev l

Streptococceae Th t b Str pt e d vided to fi g a ba d pon m ph l l and phy l gi l har t s Th p of f f these *D pl o us St pt c L o ost c* a d *P pt st pt ccus* in l d typ l ph c l coc f rm h h d ide e pl a d u lly oc u i pa s sh rt h (F g 2) The fifth g *P d c* l de p e wh h ft n oc tet d gro p n t t di i n t o pl (Fig 3)

F u of th ge bt th r e gy by f me t ti n f c b hydr t l t d mp d Th l d th pe es f th g a *D pl o* d *St pt us* wh h p od d t t

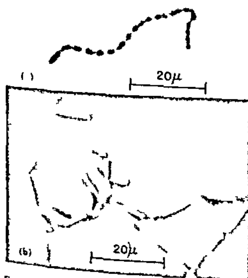
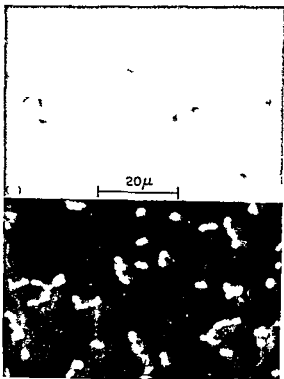


Fig 1 M rph logy f th tw t b f th Lact b lla ph t m og ph ( ) *St pt f l* tribe S pt tob ll (b) *L ct b ll b* tr b L

t l t a d p f th g *P d* wh h p od e em m xtu f l t d d *L u t p* wh h p d abl m unt l a bo d d thyl l h l d t a id dd t t l t t ry l t c d Spec es f the *fifth* g *P pt t pt c us* a b t l e p t -dec mp t p od t ll boh d at d p d a d th than l t a d a l



Fg 2 Ph t m g ph f *L st m t d* t b St pt ( ) E p l t d ll (b) Ch d p d d gl ll

Th ge u *D pl c us* n l de th pa a itic p es *D p m a* a ti ag t f l b r pn mo

The g s *St pt co* cl de n m o p t d p ophyt The ge i d ded nt f phy l g l gr up py gen d t c a d l t I g e l the fi t two c i t f l w d p d g p c p es t n the l m t y t t d n f t ns Th e o d tw g p th h h r c d p du g type a ci t d w th f rm t t n f f d p d t Sep a t f p by l g l m thod r l te w ll w th t mp t g wth a g lt t l d g wth m lk S SEROLOGY STREPTOCOCCUS

Th ge *L t* l des th h t f me t t p e so t d w th f d They w e



Fg 3 Ph t m g ph f t t d d pa d ll f *P d*

fir t ob erved in the slime ma ses of sugar facto rie They convert glucose to levo lactic acid alco hol carbon dioxide and acetic acid and in addi tion partially convert fructose to mannitol and sucro e to dextran

The species of the genus *Pediococcus* fir t iso *lated as contaminants in beer* have been observed in other fermenting foods They include the highe t *acid producing* sp cies in the tribe

The species of the genus *Peptostreptococcus* are usually anaerobic a sociated with septic and gan grenou conditions or found in the respiratory tract and may be pathogenic The species differ physiologically from those in the other genera in their growth on protein decomposition products as well as on organic acids and carbohydrate with production of carbon dioxide hydrogen hydrogen sulfide and various acids in addition to lactic acid

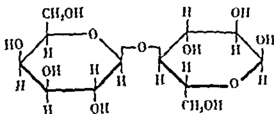
Lactobacilleae The tribe Lactobacilleae is di vided into five genera ba ed upon morphological and physiological characters

The species of the genus *Lactobacillus* include the high acid producing bacteria associated with fermenting foods and the intestinal tract They in clude two general groups The homofermentative species like tho e of the genera *Streptococcus* and *Pediococcus* among the cocci produce lactic acid as a major fermentation end product The hetero fermentative species are comparable to tho e of the genus of cocci *Leuconostoc* in their growth end products

The species of the g nera *Eubacterium Cateno bacterium* and *Cillobacterium* are low acid pro ducing bacteria from the inte tinal tract and lesions and are comparabl with pecies of *Pepto streptococcus* among the cocci In addition to lac tic acid formic acetic propionic butyric and other acids are formed during fermentation Some of the e may be pr tein degradation products They are di ided into the four genera on the ba i of morphological characters motility and cell branching The phy iology of these strict anaero be has not been c mpletely elucidated and further work may how that s m of the e species hould be placed in genera of other familie *See* Eubac teriales [c s p]

Lactose

Milk sugar or 4 *O* β D galactopyrano yl D glucose This re luc ng di a charide i I tained as the α D anomer the melting point (mp) is 20 C and the optical acti ity i $[\alpha]_D^{20}$ +85 0 → +52 6 Cry talliza tion at high r temperatures (above 93 5 C) gi the β D anomer mp 252 C and $[\alpha]_D^{20}$ +35 → +55 4 Lactose is found in the milk of mammals to the extent of approximately 2-8% *It is usually prepared from* whey which is obtained as a by product in the manu facture of chee e Upon concentration of the he crystalline lactose is deposited Lacto e is not fer mentable by ordinary baker s yeast In the ourn of milk *Lactoba illus acidophilus* and certain oth r microorganisms bring about lactic acid fermentat n by transforming the lacto e of the milk into lact c ac d $CH_3CHOHCOOH$ *See* Cheese Milk Optical ac tivity



La to«e (α I rm red g g ° 1)

Chemical evidence shows that the glyco idic linkage involves the carbon atom 1 of the D-galac tose and carbon 4 of D glucose Enzymatic studies indicate that the galacto idic linkage has the β configuration *See* Oligosaccharide [w.z.h]

Lagomorpha

An order of mammals including the pika rabbi and hares These were long regarded a rodents usually under the subordinal name Dupli identata but modern tudies how that lagom rph and ro dents are only remotely related if at all Fo il re mains of lagomorphs are abundant from the Oli o cene on but are almost unknown in the early Tertiary when the major radiati n of the tock wa taking place The hares and rabbits w r alread distinct from the pikas when they fir t appeared in the fos il record

The living lagomorphs are di tingui hed by hav ing four inci ors in each jaw in tead of t o a in rodents The central pair i enlarged and chi el like the lateral pair reduced to mall p g lying behind the central pair Numerous other feature in the dentition keleton and mu culature and serological te t empha ize the di tinctne s f the lagomorphs from the rodent The or ler i di ided into thre families The Eurymylidae containing a single known genus *Eurymyl s* fr m the Paleo cene of Mongolia lack the second pair of incisor The Ochotonidae the pika or rock rabbit are small hort eared nonl aping form m re primi ti e than true rabbit The Lep ridae are l g eared leaping animal with l ngat l hind leg In the rabbit le pecialized than the hare th young ar b rn naked and h lp le Numer u d me tic arietie ex eed d in number only by th vari tie of the d m ti dog ha e been de el ped In the hare typified by the ar tic hare and the jack rabbit the young are well furred and ha e their ey p n at birth *See* Eutheria Lago morpha fo il [D D D]

Lagomorpha fossils

The lagom rph ar l if l int thr famil the rabbit and har (Lep rida) th pika (O h t nidae) and the primiti g nera *E rym l* and *Mimolagu* (Eurymyl da) A c mp red with th r order f mammal th re i little mor ph l gi al di er ity in th Lag m rpha

L g m rph m y be re gni d b enamel t r d g t the p t r r a l f th r l r g n i

f ramen ak masset nd tempo al m le fine fenestratio s l teral rf ce of ma ill ry and som times other bo es ch ek teeth w th ro ts in arl ge a, becom o tless nd p eres t ly h rh c ed l t f rms ba ic d ntal f rm l

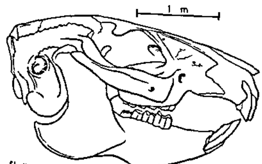
i rs $_1^2\binom{3}{1}$ ewly b p kas) can n s $_0^0$ p e

lars $_2^3$ m lars $_3^3$ *See* DENTITION

Th olde t k lag morphl ke mamm l *E y mylus* fr m the l te P leocene of M g l has j s dt th t o gly ugg t e of an ce t l l m ph b t al po e g haract that m ht be a ribed t n ecti e t an ea ly rod t. I t m diate f rm between *Eu ymyl s* and th e rl t g ther fam l s r n t kn wn P ka fi t app the l te Ol g e f Eu p d A h th ee ge e a k ow a d t n t th p e e t The d is al o p s- e t i the M ene f Af App ntly p k a hed N rth Amer a the Plioce e N rth P fi d p l ro t Pikas pp ar ir the f l re d n po h lat than th l p d alth gh pik m p m t m ph l g cally

Lep r d h good f ssil ec d M t of th ge the N w World th gh th w m d p l int th Old W ld The m j l t ry t nd h b en f m m lle c mp g l po id t rd l g k d w th u al d sal t l h b t Th refle t d the n ly h rizo t l p tu e f th sk ll n lat t th ert b l l mn f e ly f m a d a m e le ted pos t w th th fac l eg b t d w ard l t f rm Th tre d al d pl yed th l g t of l ml d fo t b es w th g t r t t fl t ral m eme t

Th ubf m ly P l l g e f the l t F e th gh l t Ol g ne th p im d l stock f th Lep d The g a *Sh m l g G b l s* d *D m t l g* f m Eur d *Myto l s* f m N th Am m y h b l t the hypoth t l l g m ph th t mu t ha g e e to both the O h t n d d th Lep l *A h l* ld t f th Ar h eola e l ed f m *P l l* i th l t Ol g ce ly Mioc M t f th l t g n w n N rth Am a b t o g n (*Pl l gus*) e h d



Sk ll d i w f P l l g h yd Ol g bb f m So h D k t (Aft A E W d 1940)

the Old W rld d ring the Pl oce e The arcl ae ol g nes became tin t in the Plei t ene

The bfamily Lep rin e incl des the li g h res r bbit and s eral e tinct gener It is n t known wheth this s bfam ly ev l ed dire tly f om the P laeol g nae r f om th Archaeolag nae

[R A S T]

Lagrange s equations

Equat on of m ti of a mecha l sy tem f r whi h a cl cal (n q a tum mecha i al) de cript n uitable a d which relate the kinet c e gy of the ystem to the general ed coordin te the gene l d force a d the time If th c figu t n of the yst m pecified by gi i g th al es of f i depe d t quantitie q q_f th re are f such e juati n f m t

I th r ual form thes equ tions are equiva lent t Newton nd law f mot n a d a e d ff e t al equat ons of the econd order fo the q as f n t n f th t me t

Derivation Let th sy t m t f N particle The m es f the p ticles are m and th carte si coord ate are x ($\rho = 1\ 2$ N $i = 1$ 2 3) Th rt c d n tes are xp e ll f t f f ($\leq 3N$) g n ral zed coord tes q q_f betwee wh h ther a no n t ai ts Th t me d n t ppear he e if the c n t t ar fixed (as will be umed)

$$x = f\ (q_1 \qquad q_f) \tag{1}$$

The de t ng t m d ff tiat n by dot

$$x = \sum^f \frac{\partial x}{\partial q} \dot{q}_l \tag{ }$$

Th cart n el ty omp nent are lin func t s of th ge e l d vel ti q

L t δq epre t sm ll d pl em t of th y tem It ut m t lly on st nt with the con t ts I thi d pl ceme t th f c f n t t d w k their nly act is t p e t m t t y to th c t nt they h e n mp n t i th d re ti of a d pla em t c i t t w th th n tr t If W s th w k d n d g th d pl me t t i do e nt rely by the te ally ppl d f ces

$$W = \sum F\ \delta x = \sum m_\rho x\ \delta \tag{3}$$

E h term n the um (3) m y r ce cont ibut o f m f of n tr t b t th y c l wh n th mmat m d Fr m Eq (1)

$$\delta \quad = \sum \frac{\partial x}{\partial q} \delta q \tag{4}$$

th t

$$\frac{\partial x}{\partial q} = \frac{\partial}{\partial q} \tag{5}$$

It is readily verified that

$$W = \sum_j \left[\frac{d}{dt}\frac{\partial}{\partial \dot{q}_j}\left(\frac{1}{2} m_p \dot{x}_p{}^2\right) - \frac{\partial}{\partial q_j}\left(\frac{1}{2} m_p \dot{x}_p{}^2\right)\right] \delta q_j \tag{6}$$

The quantity in the brackets is thus for each j the noncartesian analog of the cartesian $m\ddot{x}$.

The only quantity which appears differentiated in Eq (6) is the total kinetic energy T of the system. This is easily calculated in generalized coordinates because the connection between the cartesian velocities and the generalized velocities is linear and homogeneous. Usually the kinetic energy can be written by inspection without using Eq (2) explicitly. Thus

$$W = \sum_j \left(\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_j} - \frac{\partial T}{\partial q_j}\right) \delta q_j \tag{7}$$

Transforming the right hand side of Newton's equation is simpler. Write

$$W = \sum F \quad \delta x \quad = \sum_j Q \;\delta q \tag{8}$$

where

$$Q_j = \sum F \;\frac{\partial x}{\partial q} \tag{9}$$

is the jth component of the generalized force. By the preceding argument Q_j depends only on the externally applied forces, the forces of constraint necessarily cancelling in the summation.

The displacement δq_j was entirely arbitrary. Thus it follows from equating expression (7) and (8) for W that

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_j} - \frac{\partial T}{\partial q_j} = Q_j \tag{10}$$

These are Lagrange's equations of motion. They are valid also when moving constraints are present. See CONSTRAINT.

Examples Use of this form of Lagrange's equations is shown in the two following examples.

Particle in central force field Here the force acting on a particle acts always through a fixed point. Choose this point as origin of a spherical coordinate system with coordinates r, θ, ϕ (Fig 1). Only radial displacements involve work, so only Q differs from zero.

$$Q = Q = 0$$

The kinetic energy is given by inspection of Fig 1 to be

$$T = \frac{m}{2}(\dot{r}^2 + r^2\dot{\theta}^2 + r^2 \sin^2\theta\, \dot{\phi}^2)$$

Lagrange's equations are

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{r}} - \frac{\partial T}{\partial r} = m(\ddot{r} - r\dot{\theta}^2 - r\sin^2\theta\,\dot{\phi}^2) = Q$$

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{\theta}} - \frac{\partial T}{\partial \theta} = m\left[\frac{d}{dt}(r^2\dot{\theta}) - r^2 \sin\theta\cos\theta\,\dot{\phi}^2\right] = 0$$

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{\phi}} - \frac{\partial T}{\partial \phi} = m\frac{d}{dt}(r^2\sin^2\theta\,\dot{\phi}) = 0$$

These may be compared with the cartesian equations

$$m\ddot{x} = \frac{x}{r}F(x\,y\,\,)$$

$$m\ddot{y} = \frac{y}{r}F(x\,y\,\,)$$

$$m\,\,\, = \,\,\frac{}{r}F(x\,y\,\,)$$

in which the force function F appears in all three of the equations of motion while two of the three Lagrange equations are independent of the detailed nature of the force.

Two particles, fixed separation In this system there is one constraint, the particles being a constant distance d apart, and so there are five degrees of freedom instead of six. Choose as generalized coordinates the cartesian coordinates X, Y, Z of the center of mass and the polar angles θ, ϕ of the line joining the two particles, as in Fig 2. Then because the kinetic energy is the sum of the kinetic energy of the center of mass and the kinetic energy relative to the center of mass

$$T = \frac{m_1 + m_2}{2}(\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2) + \frac{1}{2}\left(\frac{m_1 m_2}{m_1 + m_2}\right) d^2(\dot{\theta}^2 + \sin^2\theta\,\dot{\phi}^2)$$

The equations of motion may be written down immediately, the generalized force being evaluated from Eq (9). There is one equation for each degree of freedom and the constraint is automatically satisfied.

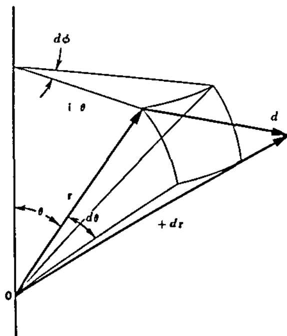
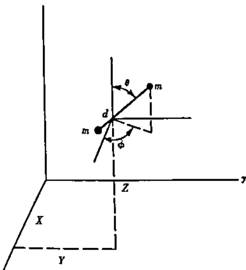


Fig 1 The vector dr is decomposed into th[ree] orthogonal vectors of magnitudes $r \sin\theta\, d\phi$, $r\, d\theta$, and dr respectively, θ and ϕ being spherical coordinates



Fg 2 XYZ rt d t f th t f f th d mbb ll m m θ d ϕ th p l gles f th f th d mbb ll t f th g t th t f m d p ll l t th fix d set f

Conservative systems In m ny p bl m th f es Q_j e de bl f m p t ntial Th

$$W = \sum_{=}^{f} Q\ dq = -dV \tag{11}$$

and th s

$$Q = -\frac{\partial V}{\partial q} \qquad \frac{\partial V}{\partial \dot{q}} = 0 \tag{12}$$

Wh n thi so t t t defi f t lled th Lagr g by

$$L(q\,\dot{q}\,t) = T(q\,\dot{q}\,t) - V(q\,t) \tag{13}$$

Th n th q t f m ti b m imply

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}} - \frac{\partial L}{\partial q} = 0 \tag{14}$$

h h th m t mm ly t ed f rm f Lagr ge equ ti

E mpl f *f L* A mpl b t n p bl m ll t t th f g l ed d t nd h w th e f ppl t f Lagr g qu ti h *T* d *V* l t ly y t bt Co d th d m l y t m f tw q l m ses *m* c ect d by p g f t n g t t *k* Let th d pl m ts f th m f m th r equ l b m po t b *x* d *x* p ti l

w t od e w coo d t $q = x - x$ d $q =$ + Th $V = kq\ /2$ d

$$T = m(\dot{q} + \dot{q}\ )/4$$

t g $L = T - V$ Lagr g q t f th t n bl a

$$\tfrac{1}{2}m\ddot{q}_1 - kq = 0$$

and $\qquad \tfrac{1}{2}m\ddot{q}_2 = 0 \quad \text{or} \quad \ddot{q}_2 = 0$

The s l t n to th first of these different al q ti ns i $q = A$ in $\sqrt{2k/m}\,t$ (ett g $q_1 = 0$ at $t = 0$) wh h i a mple harmon bration of the tw ma e Th co d equ t merely t tes th t the accel t n of the ce t of mass f the syst m s

N conse t t te y t ms Form (14) i al c t e e if th y t m i not c n erv t e provided wr te

$$Q = \frac{d}{dt}\frac{\partial V}{\partial \dot{q}} - \frac{\partial V}{\partial q} \tag{15}$$

as i the c e of h g d p ticle in a l ct oma t field He e

$$V = e\left(\phi - \frac{\mathbf{A}}{}\right) \tag{16}$$

whe e ϕ a d **A** a th l r and ecto p t tials f th fi ld r p t ely the charg f the p t l v the p rti l l ty a d c is th elo ty f l ght

Cy l c o d n t If *L* d n t d pend pl tly on part l rd te say *q* th

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_k} = 0 \qquad \frac{\partial L}{\partial \dot{q}} = \text{nstant} \tag{17}$$

H e q_k lled n g rable y l coord ate d $\partial L/\partial \dot{q}$ i tegr l f m t I th e m ple f th ce t l f field g n p evi u ly ϕ may b g d

T t l *gy* By f Eq (14) it s e th t

$$\frac{d}{dt}\left(\sum_{j=}^{f}\frac{\partial L}{\partial \dot{q}}\,\dot{q} - L\right) = -\frac{\partial L}{\partial t} \tag{18}$$

He ce f *L* d n t d p d pl c tly n th t m th p n

$$\sum_{=}^{f}\left(\frac{\partial L}{\partial \dot{q}}\,\dot{q} - L\right) \tag{19}$$

t gr l of m t U lly t th t tal gy f th y t m *S* HAM LTON S EQUATIONS OF MOTION

C nj g t m m tum Th q t ty

$$p_k = \frac{\partial L}{\partial \dot{q}} \tag{20}$$

d fi ed t b th m m t m j g t t th o-d te *q* (If Lagr n d t t b f the p f d pat f r the c j g te m m t m m t me d fi d a $\partial T/\partial \dot{q}$) Th m m t m t ar ly l m m n t m d fi d N wt m h har t d p d b th n th y t m d n th t f th coo d t *q* If *q* n gn bl c d t t j g t m m t m n t t f m t

Kinetic momentum For a charged particle in an electromagnetic field the Lagrangian may be writ ten

$$L = \tfrac{1}{2}mv^2 - e\phi + \frac{e}{c}v \cdot A \qquad (21)$$

and the momentum conjugate to the cartesian co ordinate x is

$$p = \frac{\partial L}{\partial \dot{x}} = m\dot{x} + \frac{e}{c}A \qquad (22)$$

The quantity $m\dot{x}$ is called the kinetic momentum The kinetic momentum is related to p much as the kinetic energy is related to the total energy If ϕ and A are independent of x it is the momentum p and not the kinetic momentum $m\dot{x}$ which is a con tant of motion

Relativistic systems The equations of motion of a relativi tic particle may be written in Lagrangian form The simplest way to do thi is to replace the kinetic energy T by another function τ of the ma s and velocity so as to get the derived form namely

$$\frac{d}{dt}\frac{\partial \tau}{\partial \dot{x}_k} - \frac{\partial I}{\partial x_k} = \frac{d}{dt}\left(\frac{m_0\dot{x}_k}{\sqrt{1 - v^2/c^2}}\right) - \frac{\partial I}{\partial x_k} = 0$$

Here m_0 is the rest mass of the particle Thi is accomplished by setting

$$\tau = (1 - \sqrt{1 - v /c })m c$$

which r duces to T in the limit $v/c \to 0$ The equa tions of motion in this form are till valid in only one reference frame becau e the time and the coor dinates are treated on lifferent ba es *See* RELA TIVISTIC MECHANICS RELATIVITY [P M S]

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Lagrangian function

A function of the generalized co rdinates and e locities of a dynamical y tem from which the equa tions of m tion in Lagrange form can l e deri ed (*see* LAGRANGE S EQUATIONS) The Lagrangian f nc tion is denoted l y $I(q_1 \quad q_f\ q \quad q_f\ t)$

For y tems in which the f rce are deri al le from a potential energy I if the kineti energy i T

$$I = T - I$$

If the sy tem i contin u rather than li crete the Lagrangian function I i the integral of a Lagrangian density $\mathfrak{L}$

$$L = \int \mathfrak{L}(\eta \text{ gra l } \eta . x_1 . x \ x_3\ t)\ lx_1 dx_2 dx$$

where $\eta(x_1\ x\ x)$ describe the di placement of the medium at the point $(x_1\ x\ x)$ Th equation of motion are in thi ca e

$$\frac{\partial}{\partial t}\frac{\partial \mathfrak{L}}{\partial(\partial\eta/\partial t)} + \sum_{j=1}^{3}\frac{\partial}{\partial x}\frac{\partial \mathfrak{L}}{\partial(\partial\eta/\partial x)} - \frac{\partial \mathfrak{L}}{\partial \eta} = 0$$

This formulation of Lagrange equati n appl to the motion of a gas containing ound waves to a vibrating jelly or to any medium where discrete ma es are replaced l y a continuum [P M S]

Bibliography *See* LAGRANGE S EQUATIONS

Lake

An inland body of water mall to moderately large in size with its surface expo ed t the atm phere Mo t lake fill depre sion belov the z ne of satura tion in the surrounding oil and rock material Generically peaking all bodie of water of th type are lake although mall lakes u ually are called pond tarns (in mountains) and le fre quently pools or mere The great majority of lakes have a surface area of le than 100 quare mile (mi) More than 30 well known lake ho ever exceed 1 500 mi² in extent an l the largest fre h water body Lake Superior North Ameri a covers 31 180 mi

Dimensions of some major lakes

Lak	Ar	V l (pro) 1000 ac e-ft	Sh e- l n	Depth A ft	Depth M ft
Ca p n S	1(9 300	1 300	3 30	6	3 050
S p	31 180	9 00	1 860	4	1 000
V to	6 00	180	130		
A l S	(33				
H on	3 010	3 0	1 680		
Mi l g	100	4 660			8 0
Ba k l	13 300	18 00		300	5 000
Ta g y k	l 00	8 100			4 00
(t B	11 190		1 300		
(t Sl	11 1 0		1 36		
Ny	11 000	6 800		900	310
I	9 910	136			
Wi p g	9 390		1 180		
O i	10	1 390			
B lk h	11				
La l g	000	1			
Cl l	6 00				
M bo	4 000				
I y	3 00				
On g	3 61	61			
R l lf	3 1				
N g	3 089	87			
Atl l k	3 08				
T i	3 00				
R l	11				

A fl t tes

M t lake are relati ely l all w features of th earth urfa e F en me of the large t lake ha e maximum l pth of le than 100 ft (Winnipeg Cana la Balk l U S S R Allert Uganda) A few l owe er l a e maxim um dep th wh l ap pr a h th e of me ea Lake Baikal in th U S S R i al t a mile l p at it d epest point and Lake Tanganyik Afri a i abo it 0 9 mi

Be au f their h ll wn lake in g n ral m y l on i l red e an nt f at ir of th e rth irf e with a r lati ely l rt lif in geo l gi al time F ery lak l a in f rm a bed t wh i l th lime t carrie l l y infl wi g str am t le(ited As th s liment a c um lat th e t r age c p ity of th l in i r l i ed g tati n en

c o hes pon the h ll w ma g ns and eventually th lak may d s ppe r M t l k als ha e sur f e o tlet Ex ept at elevat ns ery near sea level a tr am wh ch flow from uch an outlet gr d lly c t th ou h the b rr er f rm ng the lake b m. As th l el of the outl t s l we ed the c pa ty f the b s n is al o ed c d and the d ap-pear of the l ke red

Variations in water character Lak s differ a t the lt c t nt of th w ter nd a t wh th r th r a e t rmitt nt r perma ent M t lakes a e comp ed of fresh w t l t m a e m e alty th n the oc n Ge e lly peaking number f ater b d e h ch a e c lled a a e actually salt lak examples a th Dead Ca pi n and Aral se s All lt l ke re f d nder de tt o sem rid limat wh e the ate f e porat on s h gh e gh t p e nt an utflow and the fo e a d scharge of alt t th ea M ny le e and o l kes t term tt nt om time ex t g only f b rt p d afte he vy ra a d dis ppe ng nd t te ev p r tion Th s lakes are called play in N rth Am ri a h tts n N rth Af a d th names el wh re In s h eg th s la e a a d v l m f perma e t lakes m y d ff r e orm u ly f om w t to dry a so

Th t r f th mo pe man t alt lakes dif f rs gr tly the d gr e of l ty d the typ of lt d l ed Comp red to typ al c an w ter (pp m t ly 35 parts p tl an l ppt) m lt l kes e y lty G at S lt Lake water has a d l ed l d nt nt ab ut fo t mes that of sea water (150 ppt) a d the D d S a b ut e e times (246 ppt) Some l the l g r alt l ke h e m h low d l ed ol d nt nt s th A l S a (11 ppt) a d the Ca p a S (6 ppt) The mpo t n of lt d p d p rt n th geol g l h a ter f th d a g e d h rg g nt th lak p t o th ge f th lake d in part th e es f t p r t n o e i fl w A at t n pp bed the s lts mmo n u fa at r a e p e cp t t d n u h an o d th r m gnes m hl de d l m hlo d em n m sol t fte th r lt h p y t ted

Lak w th f h wat r ls d ff g tl n th compo t n f th w t B u l th bal bet een t fl w d utfl w f esh lake w t r m po t t nd t ume th mp te d l d w ld h a tes t c f th w t s f th fl w ng t am—w th th l k age h l ttl n fl n e Lakes th a l gg h nflow p rt cul ly h re nflow g ter h te m h o t t w th m g l g t t tend t ha e w t s w th h gh l ke p d r g wh re dra n ge m es th gh a t p g aphy l gl l m l kes f rmed w th d g a ha t g r t ll m t m ph l n try r k t nd t ha e l d sol ed solid o t t Th s Lake S p th t m j d n g f m th Lau t n Sh ld ha d sol ed sol d t nt f 0 05 ppt Th wat r f C m l Lak n th high Alp S t zerland has a d ol ed s lids c ntent f only 0 0085 ppt Lakes w thin l me t ne or dolomit c drainage areas ha e a pron unced calcium car b ate and m gne um a bo at c ntent As in all surface w ter d ol ed g e n tably oxygen al o are pr e t n lak waters Und r f w pecial t uat o s as rate l ke in lcan c a ea sulfur or other g es may be p e e t in lake water influenc g col r ta te and chemi al eacti n f the wat r *See* SURFACE WATER

Basin and regional factors Mo t l ke ar nat ral a d a l rg prop rti n of them l e in d pr s s n of gl cial o ig Thu alpine l cation and regi n with g und m a ne or gl ci lly *eroded* exp ures re th t s f *man* of the wo ld lake The l kes of Swit erl d M nn ota and F nl nd re pe ti ly re w ll k own lli t tion of the e types

Lake m y b formed i depre io s of diff ring glac al gi (GLACIATED TERRANE) (1) ter ra n er ded by c ntinental gl er with the u f ce differ tially deepe ed by ic abr ion of r cks of vary g h rdnes a d resi tanc (2) al ley e d d d ffe e t all by alley gla ers (3) ci q ie (glaci lly ded alley head n mo nta n) (4) l teral m raine b ri r (5) f nt l m ra e b rrie (6) valley gl cier barr er (7) eg l rit in the d p t of gl l drift r g und m ine

Lake a e p t cul l imp rta t rf fea tur in th p nepl d ient ks f th Lau nt an Sh ld a d tl Fe n a dian Sh ld of o thern E r p The l ke gion f n thern N th Am ica wh h nt th Lau e t an Shield pr b bly h one-fifth t o e-q arter of t fa e n l ke Ma y t eams the e e s are inter rupt d mo than h lf the r total length by l ke Lakes on the h eld a a rul a land tudded a d h t em ly r gular outl ne The m t p m ne t l ke l n the h ld them l e Ma y u h lake n recently e o red h eld h v fr h h d k r i ith h h res t n to o t th utl t B a f g lly l w t e m g d t a d l ttle l m nt ca ied th b d ng d dep t t m t ns a e l w A a lt the l fe f all b t th m ll lake i th e a p b bly w ll b m d in term f wh le g ol g p r d

Some l kes in gl c lly formed d p es on s w ll ther b may b e n d d b r er lake The gla l l ke a e f rmed n gla l d ft beh nd l t l f ntal m ra b rr e l dd t dep e ns f ffici t d pth to conta n a lak m y b f med by (1) ed m nt depos ted by t ams (all i m) al o t e m b rne g t ti e d b a tr dam th d t b ta i a d h d d e c u e f th l we Mi s pp V l l ( ) l d l d n m u t n u a (3) nd d e (4) i r m b h a d e r r t bo ed m ts al g th h r s f l rge bod es f wate (5) l fl w (6) a t fic al o ma mad b ri

A l rg p r t g f lak i f nd n th r the gla lly f rmed r barrier f rmed depr

sions However a few other types of depres ions contain lakes (1) craters of inactive volcanoes or calderas (Crater Lake in Oregon is a famous exam ple) (2) depre sions of tectonic or structural origin (Great Rift Valley of Africa includes Lakes Albert Tanganyika and Nyasa) (3) solution cav ities in lime tone country rock (4) shallow de pressions cau e a dotting of lakes in many parts of the tundra of high latitudes

Conservation and economic aspects The lakes created behind manmade barriers are becoming more and more common features to serve multiple purpo es Examples are Lake Mead behind Boul der Dam on the Colorado River Lake Roosevelt be hind Grand Coulee Dam on the Columbia Kentucky Lake and other lakes of the Tennessee Valley and Lake Tsimlyanskaya on the Don

Both natural and manmade lakes are economi cally significant for their storage of water regula tion of stream flow adaptability to navigation and recreational attractivene s A few salt lakes are significant sources of minerals Recreational util ity long important in the alpine region of Europe and in Japan is now a major economic attribute of many American lakes Economic value is generally increased by location near substantial human set tlement Most of the world s lakes however are lo cated in regions where they have only minor eco nomic ignificance at the pre ent time [F A A]

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Lambert

A unit of luminance (photometric brightness) that i equal to 1/− candle per quare centimeter It is al o defined a the unif rm luminance of a perfectly diffusing surface emitting or reflecting light at the rate of 1 lumen per square centimeter The lam bert a large unit is satisfactory for expres ing high values of luminance from b right light sources For more mc derate alues of luminance as fr m fluore cent lamp or reflecting surface the milli lambert (0 001 laml ert) or the foot laml ert is generally u ed

The luminance B in laml ert is

$$B = -dI/(dA\cos\theta)$$

where I i the luminous inten ity in candle A i the urface area and θ i the angle l etween the normal to the surface and the line of sight *See* LUMINANCE PHOTOMETRY [R C P]

Laminar flow

Streamline flow of a i cou *fluid which ati fie* the Navi r St ke eq iation *of moti n In laminar* flow the fluid move in layer without large ir regular fluctuation (*s e* TURBULENT FLOW) Lami nar fl w occur at low Reyn ld number Thi c r re pon l to the c ndition c f small el citie and dimensions of bodies to very large vi co ity or to mall *density of the fluid Laminar flow plays an* important role in everal practical problem

The flow of oil in the bearings for lubricatic n is laminar The theory of laminar flow hows that under great normal pre sure the oil in the bear ing has only light frictional resi tance

The motion of a minute particle in a viscou fluid produces laminar flow The drag coefficient of such a body is inver ely proportional to its Reyn olds number

Flow on the urface of modern aircraft and mi *siles flying at extremely high* altitude may be lami nar The Reynolds number for this ca e i u ually moderate and the vi cous effect i confined to the boundary layer region of the body Laminar l u d ary layer flow determines the kin friction and the aerodynamic heating of the e bodies *See* NAVIER STOKES EQUATIONS REYNOLDS NUMBER [S I P]

Bibliography S I Pai *Viscous Flow Theory* vol 1 1956

Lamp (electric)

In the common incande cent lamp a re i tance wire such as tungsten i heated to incandescence by an electric current In a vapor lamp the pa sag of electricity through mercury vap r or sod um vapor serves to ionize the gas and prod ice a br l liant visible glow di charge Inert ga es may be *u ed in place of vapors t give other* col r of light as in neon lamps and in lumin u tul ing for advertising igns A fluore cent lamp i a type of vapor lamp in which the radiation from i n zed mercury vapor is converted into a more uital le white light l y fluore cent coating on the in ide of the gla tubing In an arc lamp *the light i pr* duced l y an electric arc pa ing through the pace between two electrode *See* ARC LAMP FLUORE CENT LAMP INCANDESCENT LAMP VAPOR LAMP [J TR]

Lamprey

Any of se eral pecies of very primiti e vertebrates belonging to the cla s Cyclo tomata Lampre are el ngate cylindri al animals without jaw scales r paired fin They are dark grayi h t l lui h bla k *in col r and are richly* upp lied with a slimy m u to protect their thin skin

Typically lamp rey are external l lood ucki g para ite n ther fi he They attach them el e t the victim l y mean of a round uct rial m ith Armed with h rny denti le th ey ra p the kin (*the l o t until it l egin t l le* l an l s k l l l f m the woun l until their l unger is sati fed Th y dr p off and hi le in th e mud until th y n l m r (l



Sea l mp ey P t omyzo m ; l gth to 3 ft (F om E L P lm F ldb k f N t l H to y McG w H ll 1949)

Th e both f e h w ter and m pecies M t f th m a e f l ttle imp ta e the o e c pt bei g th Great Lak ace of the e l p ey *P t myz m rin s* I re ent ve th d p edat n f th large lamp y h rtually dest ed the l ke tro t nd wh t fi h fi heries in the C t Lak depr i g comm l fi h m f m'll f d ll

I th p g lamp ey mi te p t m or fr m th t c a tal treams t b uld a ne t of pebbles All ad lts d ft p wn ng Th l rv dev l p i (h m d q uet eddies and stra plankt nd c deb is from th w t th o gh th g ll sl t u til th tt maturity wh ch m r q re 3–7 year Wh they cl ang t th ad lt f m th d ift d w tream t l g r water h e the t k p the pa t l fe M st pa t l mp ey lt ad lt f a per d f about o e r

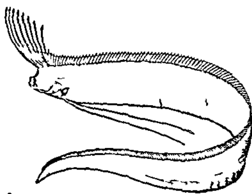
Th e r l ev l no p a iti sp alled b ook l mp ey The ly d l pment d app a e irt lly d t cal t th t of th p t pec Th y d t feed ad lts p n soo ft r t a f rm g d d e few d y S CYCLOSTOMAT (CHO DATA)

[J D B]

Lampridiformes

Th ribbonfi h a fi h p h d th alle l o k n th All t og th Alth h th fi hes e d f rm th y ha h r ter th t d fi e th de f a t opt yg fish h h appe t b r l t d t th B r f rm The fi e c p d f ft r th dor l h l ? a t r p n n rh t phe d bon p e t the p l c fi th with 1 17 ray the p l g dl rt d b tween the c ds o att hed t them th wimbladder w th t d t mes d a d p th t re b t a d th m ll lly p ot t le M t spec e l ge nd som mm ly th e f se p nt t

Th l mp d f m fi h d te f m th Ol go They mp 5 f m l 8 R t g d



Oarfi h R g l gl l gth t 20 ft (Aft D S Jord d B W E m Th F h f N rth nd Middl Am US N tl M m B ll 47 1900

perhaps 12 pecies All are oceanic l ing at hal l w t mode te depth *See* ACTINOPTERYGII

[R M B]

Lamprophyre

A y f a g p f gneous rocks cha te i ed by a porphyriti t t e which al d t l ge crystal (phe ocrysts) f d k l ed (mafic) m er l (biotit mph b le pyr xene or ol e) app et i n aphaniti (t v ibly c y t l line) mat x As a gr p the e dark ck are char act ed by (1) a bundan f mafic m e als i associati w th alk l ch feld p (2) the pre en f mafics both a ph rysts d in th ma t x and (3) n ab nd nce of m fic ph cry t in the ab ce of feld par ph n cry ts Lampr phyre a chemically un l They h e a l w s l a con tent a d h gh i mag e um nd alk li c tent *S* PHENOCRYST

Varieties of lamprophyre M ny ri t of l mpr phyre e known but nly th more common ar sh wn n th ac mpa y g table

C mmon l mp phyres

Pri pal d gnos m fic	Principal f ld pa		W hou f ld pa	
	Alk l f ld pa	Pl giocl se	W h ol	W hout ol vi
B te Hornbl od	M Voge	K rsa t te Spessa te	Al oi	O h t
B k k		Campton te	M nch qu t	Fou hi

M tte t sit k sant t d sp sa t t The f m t mm n types e mi ett ge te ke s t te nd pe art t The fi st tw ar c mm nly f d to a sy nit lamp pl yre the l st t a d t lamp phyres U d the m ope l rg h g l pl t f b tit sl w z al stru t e with p le yell w m gn si m rich c t s nd red b wn n h b d r I some rock the e rystal ar c rr d d Sl de p i m needles of g n b own h r bl d a *mm n* Py x ne g er lly d p d a g te b t in me rock a t t m h ug t b d nt Ol r r n m t type b t i c mm pes art t

A la ge p p rt n f the k m t ix i m p ed f f ld p r Pl g o l se (lb t a des) form g l g n or p ly d l p d l ths nd may h w z l tr ct with l m h c es d od m h b d s *P t h feld* p r lly rth l d c u i eg la t ct gul g n nd c mm nly n l e th m al a ab nd nt tiny g a n Q a t m y b m t tu nt a d wk n p t i int t t l A e ry m l i l de ap tite ph nd m g ett t

C mpt u Th mm lamp phyre c mp t n t h t i d by th p e c f ba ke ik t d l b ad ite d feld p Pyr b t t a d l may m y n t b p e nt

Al t d u ch t t These te e r e b t t l mp phy They f ld p f but rv m ll t r f ld p th d Al o t ch a te ed by lep d m l phe oc y t d by th p es-

sions. However, a few other types of depressions contain lakes: (1) craters of inactive volcanoes or calderas (Crater Lake in Oregon is a famous example); (2) depression of tectonic or structural origin (Great Rift Valley of Africa includes Lake Albert, Tanganyika, and Nyasa); (3) solution cavities in limestone country rock; (4) shallow depressions cause a dotting of lakes *in many parts of* the tundra of high latitudes.

Conservation and economic aspects The lakes created behind manmade barriers are becoming more and more common features to serve multiple purposes. Examples are Lake Mead behind Boulder Dam on the Colorado River, Lake Roosevelt behind Grand Coulee Dam on the Columbia, Kentucky Lake *and other lakes of the Tennessee Valley*, and Lake Tsimlyanskaya on the Don.

Both natural and manmade lakes are economically significant for their storage of water, regulation of stream flow, adaptability to navigation, and recreational attractiveness. A few salt lakes are significant sources of minerals. Recreational utility, long important in the alpine region of Europe and in Japan, is now a major economic attribute of many American lakes. Economic value is generally increased by location near substantial human settlement. Most of the world's lakes, however, are located *in regions where they have only minor* economic significance at the present time. [F.A.A.]

Bibliography: R. E. Coker, *Streams, Lakes, Ponds*, 1954; P. H. Kuenen, *Realms of Water*, 1955; F. C. Lane, *The World's Great Lakes*, 1948; U.S. Army Corps of Engineers, *Survey of Northern and Northwestern Lakes*, Great Lakes Pilot Bulletin 60, 1951.

Lambert

A unit of luminance (photometric brightness) that is equal to $1/\pi$ candle per square centimeter. It is also defined as the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of 1 lumen per square centimeter. The lambert is a large unit and is satisfactory for expressing high values of luminance from bright light sources. For more moderate values of luminance, as from fluorescent lamps or reflecting surfaces, the millilambert (0.001 lambert) or the foot-lambert is *generally used*.

The luminance B in lamberts is

$$B = \pi\, dI/(dA \cos\theta)$$

where I is the luminous intensity in candles, A is the surface area, and θ is the angle between the normal to the surface and the line of sight. See LUMINANCE; PHOTOMETRY. [R.C.P.]

Laminar flow

Streamline flow of a viscous fluid which satisfies the Navier-Stokes equations of motion. In laminar flow the fluid moves in layers without large irregular fluctuations (*see* TURBULENT FLOW). Laminar flow occurs at low Reynolds numbers. This corresponds to the conditions of small velocities and small dimensions of bodies, to very large viscosity, or to small density of the fluid. Laminar flow plays an important role in several practical problems.

The flow of oil in the bearing for lubrication is laminar. The theory of laminar flow shows that under great normal pressure the oil in the bearing has only slight frictional resistance.

The motion of a minute particle in a viscous fluid produces laminar flow. The drag coefficient of such a body is inversely proportional to its Reynolds number.

Flow on the surface of modern aircraft and missiles flying at extremely high altitude may be laminar. The Reynolds number for this case is usually moderate, and the viscous effect is confined to the boundary layer region of the body. Laminar boundary layer flow determines the skin friction and the aerodynamic heating of these bodies. *See* NAVIER-STOKES EQUATIONS; REYNOLDS NUMBER. [S.I.P.]

Bibliography: S. I. Pai, *Viscous Flow Theory*, vol. 1, 1956.

Lamp (electric)

In the common incandescent lamp a resistance wire such as tungsten is heated to incandescence by an electric current. In a vapor lamp the passage of electricity through mercury vapor or sodium vapor serves to ionize the gas and produce a brilliant visible glow discharge. Inert gases may be used in place of vapors to give other colors of light, as in neon lamps and in luminous tubing for advertising signs. A fluorescent lamp is a type of vapor lamp in which the radiation from ionized mercury vapor is converted into a more suitable white light by fluorescent coating on the inside of the glass tubing. In an arc lamp the light is produced by an electric arc passing through the space between two electrodes. *See* ARC LAMP; FLUORESCENT LAMP; INCANDESCENT LAMP; VAPOR LAMP. [J.M.R.]

Lamprey

Any of several species of very primitive vertebrates belonging to the class Cyclostomata. Lampreys are elongate, cylindrical animals without jaws, scales, or paired fins. They are dark grayish to bluish black in color and are richly supplied with a slimy mucus to protect their thin skin.

Typically, lampreys are external blood-sucking parasites on other fishes. They attach themselves to the victim by means of a round suctorial mouth. Armed with horny denticles, they rasp the skin of the host until it begins to bleed and suck blood from the wound until their hunger is satisfied. They drop off and hide in the mud until they need more food.



Sea lamprey (Petromyzon marinus), length to 3 ft. (From E. L. Palmer, Fieldbook of Natural History, McGraw-Hill, 1949)

Spec fic t tment q ite as ff t e as with the fi e m thod of dentific t o There a e t mes when streptococ m t be l b l d The e o l deep d m s nd tudies the r tion patte n f th ho t, e pec lly ch n unde ble the matic fe er where pre e t ght For h ch t d the Lancefield erol g c tech q are of great alue *See* MASTITIS (cows) RHEUM TIC FEVER SCARLET FEVER STREPTOCOCCUS [P L.B]

Lancelet

A y m mber of the ubphyl m C ph l h d t phyl m Chord t There e o ly tw gene a *B ch t ma* d *Asymmet o* and a total f nly 30 pecies *B a ch toma* i the b tte k wn d th a mal u lly m t when refe e is m d t th l elet or t is m mm nly c lled mphi us

La c l ts l n hall w wat burrow g loose d w th th h d p t di g They ccur n th w rm nd tempe at s and e wid ly d tr b ted i cl d g pe alo g the so th rn c a t f the U ted St t They e som t me ed l food

rv d
ph d gm t l m l
toch d f y do l f
t l
f
l m g ll lt l g d t p
t m l t
d tyl

Th l l t mph B h st m t l bout 2 l g (F m T l St d R L U g G l Z l gy 3d d M G w H ll 1957)

Amph bo t 2 r l s l gth d s m l in appe r c t a m ll t a pa ent fi h It h t h d the f ll l gth of th body w th a se es f pa ed g ll sl t pen g t n t l ty The e m ll d t ct d l t b l nerv y tem w th n a te r e l rg m t La el t re f p rt l i t r t t ol g t bec th y ppe r cl t th n est l l f th ert b tes They r m l i an t my t th l rv l Cy l t m ta S CE H LOCHOR ATA

[J.D]

Land use planning

Th d ected of la d a d the nat l r o th f m f the p ed t rm d p po f the soc t l t h h pl n g i t s rv A pl g f m t t f f t l d r l est t b- d n it m y be mb at f d d al h p i cl d g both p t a d publ l d l th l tt e th pla g u t lly

cides with the boundaries of some go ernment l ju i d ction h a a city county t t some reg l c mb ati f these

Th object e of la d use planning on an nd i d al ow hip may b imply that of maximizing the net i c me of th owner The object e of land u e planning by a publ c agency however is more c mplex a d i inte ded t maximize long range c mm ty b fit Ach ing the c mmunity go d often requ res me l m t t n upon the freedom f i d idual owner t s ther l d as they choo La d pla i g deci i ns req b l nc g con flicts of int est m g ind id ls and betwee pri te and publ c e d ors Th e dec ions bas ically i l rec ncil g d ffe i g val e structur m g the ind du ls compri g the c mmunity within the pl ning a

Origin of land use problems The tra tio from an ea ly s mpl e omi a d s c l orga za t n t a m d comple nat l ec my has e ted ma y land u e p oblem The fro t er men li ed d ectly f m the l d a d their depe den up ther was l m ted T d y peopl a e j t a depende t upo the la d but their rel t hips t it a d t ea h ther e m e c mpli ted At the s me time d mand re m e ried the pre su e o the la d e ce m re i t t d the need f l nd u e pl i g m re mp lli g

Th e cha cte t cs of tal a d co m hi t y nu t ed nt mpor ry l d u pr blem F t tr g mp t t e f r es pr moted by a ph l ophy of f ee p ate e terp ise u ged rap d u ord l d expl t t of la d nd it e e Th xpl tat n was ha act r ed by e t us ste d f te method k ow t mode n t hn logy It so ght t m x mi e im m d t m eta y r t s to the pe to r ther th lt m te b efits t c ety T d y th meth d d p ttern f early u e e decl ed w t f l t rms f cu e t need te hn logy nd o omi s P bli pol y attempt to sat fy l ng r nge need f ciety m e d q tely a d t d s ch w te by fl e c g method d p tt rns f la d us th gh r s pl n g eff rt

Sec d e ly l d e pl tat dem n tr ted l t tle de t d g of tu al l d p b l ty The pl w foll wed the a e n m ny e s wh ag i c lt c t d a well as f t th plow b k th pl i m ny pl s whe cr ps r n t a mp t bl with the l mate a m r d ght s t t f ag d th plow ha tur d the s d f fi ld wh h by t e f s il h r cteri ti s and s f e l pe ca t pp rt c lti t with t r p d d s il d plet Th e d t h e du ed p bl c pp rt f l nd u e plan ng d gn d t h i g m th ds of h sbandry i l e w th th t l cap b l t es f th l d

Th d e ly c ty dev l pm nt, th b ce of l d p l y a d pl n re lt d nd s- c m n te m t e f de t al i d t al d mm l l d Co s qu tly denti l fte ff ed d fl t d l and c mme i l d d t l t pr s f l d t ach p

ence of melilite perovskite olivine and carbonate in the matrix Ouachitite is devoid of olivine and may carry more or less glass and considerable augite as phenocrysts

Monchiquite and fourchite The rare types monchiquite and fourchite lack feldspar but carry more or less barkevikite in addition to augite biotite analcite and glass Monchiquite is distinguished from fourchite largely by the presence of olivine

Alteration products Lamprophyres are highly susceptible to weathering and many are so completely decomposed that it is impossible to do more than approximate their original mineral composition Common products of alteration include carbonate chlorite serpentine and limonite

Occurrence Lamprophyres occur most commonly in small or shallow intrusives (dikes sills and plugs) and are frequently associated with large bodies of granite and diorite Lamprophyre dikes may form parallel swarms or as at Spanish Peaks Colorado may form groups which radiate from a common center

Formation Lamprophyres form in a variety of ways Some are products of direct crystallization of lamprophyric magma (rock melt) others represent older rock which has been converted by metamorphic or metasomatic action Normal basaltic magma may be made lamprophyric by assimilation of foreign material That such a process has operated is suggested by the presence in some lamprophyres of abundant foreign rock and mineral fragments The mafic phenocrysts commonly show strong resorption indicating they were not in equilibrium with the adjacent liquid Early formed mafic crystals may settle out of a deep slowly crystalizing magma Clusters of these may be reincorporated in the late alkali rich fraction of the melt just before it is erupted to form lamprophyre at higher levels

Some normal basaltic dikes appear to have been transformed to lamprophyre after solidification This metamorphic or metasomatic change could have been accomplished by vapors or fluids which were driven out from the deeper crystallizing portions to permeate and alter the solidified portions above Similar emanations from deeply buried granitic masses may be channelled along dikes of basalt or diabase in the overlying rocks and convert them to lamprophyres

Some bodies of lamprophyre which resemble dikes may not actually be intrusive They may have formed when solution or fluids from depth moved up along fractures and reacted with the adjacent rock and converted it to lamprophyre *See* DIABASE IGNEOUS ROCKS METASOMATISM [C A CA]

Lancefield differentiation scheme

An accurate means of identifying most streptococci The procedure was determined by Rebecca C Lancefield and it applies to those streptococci the β hemolytic types which have major significance Strains from many sources can be classified in terms of their natural host with ability to produce disease in this host as well as in other hosts However the immunochemical (serologic) differentiation system of Lancefield depends on the presence within the bacterial cell of a specific carbohydrate the so called C substance which determines the group The definition of the group depends on the precipitation of the C substance in a clear bacterial extract with appropriate rabbit antisera Designations of the group now 13 in number extend from A through O with two alphabetic omissions

Those streptococci of Group A are almost always responsible only for human illness Most strains of Group B are from animal and are especially important in producing mastitis or udder infection in cows Group C is unusual in that it includes both animal and human pathogens and distinction cannot be made by this method alone Group D streptococci are found in dairy products and in the intestinal tract of man and animals They are a cause of urinary tract infection and of subacute bacterial endocarditis which is an infection of the inner lining of the heart, especially the heart valves Subacute bacterial endocarditis is a complication of congenital or rheumatic heart disease Both human diseases represent the ability of ordinarily benign organisms to be pathogenic when there is some basic deformity which interferes with normal function Streptococci of Groups E and N are found in milk cream and cheese but have no relation to infection Groups F and G are occasionally human pathogens while H and K strains do not provoke illness People may harbor those of Group H K and O which are almost uniformly innocuous Dogs likewise merely carry Group M streptococci but canine illness can be caused by strains of Groups L and C

F Griffith at the same time the Lancefield system was developed utilized agglutination to define types within each group Agglutination is a serologic method in which intact organisms are clumped by appropriate typed rabbit antisera There was a time when both methods were used one for the determination of group the Lancefield precipitin test with type selection by Griffith's agglutination test It was later noted that the type found by both methods need not be in complete agreement This led to the study by Dr Lancefield and her associates of the bacterial antigen or chemical substance concerned It was found that two proteins M and T were involved in differentiating types within groups Only the M substance of the Lancefield method was specific for each type of microorganism while more than one T substance could be present

Serologic classification is not commonly employed since it is time consuming and not always necessary In a clinical hospital laboratory for example streptococci can be satisfactorily and rapidly recognized by their typical appearance on suitable growth medium Appropriate signs and symptoms in the patient are supportive evidence

of the eso ce pla ner Th s imp r t e in the e p tte n f hum n ettl ment wh ch s evol ng in the U ted States The o rlapping metr poli es m t be planned t meet the ba i eg onal n d f r ate a t d p al tr n portat o and op spa e for l ght ai and recr ation with due e gard t th natu al capabil ty f it en ronment to ta n optimum le el of reg nal ec n m c opportu it a d oc al am n t es Community requ r ment and the nat al e nm t l ap l lity h ld find ee c l t on in a n w type f n t gr ted re l des gn

Sec d n rd r to fa litate so de public plan n g dec t da d d c ite a t gud la d u e allo ti mu t be dev l p d by th t d nt a d pr tut f la d u e pl n ng a d be e por ted n p blic la d p l e H t icall th f e ent p c n m ha elied upo the m ket t allo ate l nd and all r es The h ghest p c det rm ed th u e to wh ch th e e uld l put The ed f r l nd u pl n g an es f m th f lu e f th mark t alway t llocat la d t the be t u f om the tandpo nt of th mm n t Th if pl n ng i t me t t hall g it m t dev l p gu de f p bli e source allw t wh h will more ly eh e the comm n t g od in th e re a d fo th e p poses wh r th m k t f d want g

Th d f land pl n ing s to be mad n i t u m s of democ acy mp m nt e q ed in the m th ds by wh h c l eh i of th maj r ty find e p t th pl nn p es F l pl n d s wh ther th appr n f gne l r t i to la d u e ll at o f p c fi pla h uld be m de by p ple of th m mu ty th h th p ti n f th p l t l p c es Land u e pla n ng in the fut e m t d l p han l th ugh wh ch t an b m t cu l i serv g the p l t c l p nd n r p nd i g to t N w th ught nd pe im t ti n h ld be appl ed t the c mpo it n a d ele t on f the pl n i g org n zat o n th h f r a tr t re th t w ll p e entat n f the mm n ty a d p o de p t t ag n t m f m self seek g te est

F rth de bett r t th t pl ill b arr d ut, l r r l t h p m t be tab l hed b tw n the pla n ng a th r ty nd th g n es wh h e e p r f implem ntat n Ch ter ti ally a e ty pl nn ng mm n i establ hed som hat p rt f m th mt n r l g rmm t, th nly p l l tho ity labl t impl m t th pl n In gly regi al pl n g bod es wheth o i nt d p m l t la g m t polt eg n r t la g e d el p- ff ct f wh h n gl go nm t l body these t t mak it d ffi lt t m h th pl n ent es f th pol ti al nd adm n t t en es hall ged t d r i t tut l f rm a d p oced es th gh h h th pl g p oc

and the publ c p w r f implementat on ca r act r pon ibly one t th ther

In the m d tw nti th cent ry e e ce and te h nology an wr t f om the e rth pract c ll any th ng The criti al problem in land u e planning of the futu e ar s f om the diffic ilty of deter m n ng wl at i ou ht The e problem are n t s i nt fi nd technol g in the t ual e e but they are human n They inv l e r c ncili g differ nt human d ir and rg n zin f r co p r t de c s ns and p ogr ms f act o Th hall n i to fi l m a s of one ptu lly nd m th d l gi lly m ld ng the natu al e c l a ed techn l gie into a e r nm ntal fr mew rk with the applied so i l cie ces to pr d ce a l nd u e heme to n man be t *S e* AGRICULTURE FOREST A D FORESTRY *s e lso* FOREST CO SERVATION RANGE LAND CONSERVATION SOIL CONSERVATION WATER CON ERVATION [L F C]

Bibl o raphy Se CONSERVATION OF RE OURCE

Landing gear

Th e p rt f an a ft tr tur wh h erve t upp t th r raft when t n t i tl e a r fi wh el b ake h ck t it dra tr t nd mi cell n u eq ipm nt l as t acting me ha n m tee i g me han ms himm damp and door the m j n t f n ai cr ft la di g gea F r sp c l p rp s tf wl l and tir may b epl d w th k d r k A landi g ge r q ed n ll pil ted a cr ft It p o de a me f ppl g f c n rm l t th g d f ffi i nt m gnt f a d d at n t d t the flight p th fr m int r e t g th und t on pa all l t th g i d dur g l nd g a m an f ta d g f wa d m t n by of b ak and a m ns for *t p t ng* p it on ng and m v ng the a rpla e o th gr u d R qu me t f land g ge mpo e a we ght pe lty f 10–20 of th st u tu al we ght f the i plan fr m wh ch th h le recei e n be eft o ce t a borne The l n p f rma a d pa l ad b cau e of th we ght i e a d ign r t g g at d al f att nti n to the la ding ge when a n w air pl e i des g d

Landing gear arrangement Cur tly th m t wid ly c pt d a r n em nt i the t icy l l nd n g a (Fig 1) Th ar ang m t plac a n e g w ll i rw d f th c nt f g vity n the fu l g d t o ma n gea l ghtly aft f the ce te f gra ty w th uff i nt d ta ce b twee them t p d tab l ty ga t ll g d ri a ya d l d ro wi d d r ng ground m n r The o g p e ent n g whe b ak s a appl d The n e g a wh h s lw a t d often eq ipped with power teer ng t ll g o d m n u ng

A ld ti al be fit fr m tr cy l nfigu t r that (1) th enter f gr ty f rw d of the m in g a lt n i a figu at n wl ch i nh ntl d ect n lly t ll d i g la d g (2) the p l t i b l ty i g od (3) th flo f th ai c aft i e ly l el whe th a pl n n

ble economies in such services as transportation power and waste disposal As deterioration of the central city set in residences stores service establishments and industries favored the suburbs for new location This situation makes forcefully evident the need for public decisions and public controls on major aspects of land use in the central city and in the mushrooming suburbs of every metropolitan center of the country

Principal planning areas Early land use planning efforts sprang from two apparently distinct and different problems areas (1) rural areas where the planning task has been concerned largely with giving more conscious direction to the use of land for natural productive purposes (crops forage forests wildlife fisheries or water flow) and the goal has been to direct the use of the land in accordance with its capability and (2) urban areas where the planning task has been principally concerned with space arrangement of major urban land uses In this case the goal has been to design the city layout to achieve greater convenience safety and economy in urban living

Rural land planning emphasizes the development of land use pattern which serve man s long range needs and at the same time reflect the natural resource capability that is the physical and biological limits beyond which long run depletion of the land resource will result Increasingly private land operators are learning that production according to land capability is good business There is also increasing recognition by the public that there is a major common interest in intelligent rural land use planning The Federal government provides various inducement and aids designed to improve rural land use Local and state government are experimenting with land use controls for example zoning lands for forest and pasture which are unsuitable for crop designating lands well suited to farming as agricultural and marking out for future subdivision those area best adapted for that purpose

City land use planning originating from the desire for the city beautiful has moved from an emphasis upon aesthetic design to functional design It attempt to anticipate long range needs for urban services through the study of growth trends and to design a pattern of land use which will promote convenience and economy in supplying urban services as well as an aesthetically pleasing space arrangement Recent policies of both Federal and state governments encourage cities to conduct a continuing planning program

Since the great depression of the 1930 both Federal and state government have cooperatively organized studies for the purpose of developing plans for improved productivity of land and related resource of various large natural regions of the nation The Great Lake Cut Over Region and the Northern Great Plain were area early subject to such regional studies The creation of the Tennessee Valley Authority in 1933 marked a further emphasis upon regional resource planning TVA and later endeavors in river basin development have had as their primary planning objective the discovery of improved economic opportunities and social amenities which could be realized by a planned use and management of the land water and related resources

This objective stands in contrast to the early more limited view of the city planner forester and conservationist The early city planner looked at the blighted city and visualized its rehabilitation He studied trends and sought to design his city layout for the inevitable growth He had little concern with questions of planning to promote growth The early forester and general conservationist dwelt on natural limitations and emphasized protective measure to avoid continued misuse Later measure based upon land capability and scientific husbandry were formulated These measures first emphasized the repair and rehabilitation of the physical and biotic environments which suffered from past misuse Gradually the increase of goods and service from natural resource has become an additional justification for the conservation measure Comprehensive regional planning now purports a positive integration objective for land planning designed to achieve maximum net social benefit (economic and noneconomic) for the use of the land now and in the future

The growth and importance of regional resource development is indicated by the rapid expansion since World War II of Federal state and local resource planning activities Notable are program in regions such a the Ohio River Basin the Missouri River Basin the Columbia Valley the Central Valley of California the Arkansas White and Red river basin the St Lawrence Valley the New England and New York region and the Delaware River Basin In addition hundreds of local organization such a watershed association various special district and intergovernmental planning committees have sprung up in response to land use problems in a variety of area Often these smaller region may be dominated by a vigorous urban center Here rural type resource development problems intermingle with the problem of space allocation and design of the spreading urban area Land use planning during the last half of the twentieth century is challenged to meet the need of a new planning area one composed of overlapping metropolis and involving new admixture of rural and urban land use problem

Land use planning and the future Current trends in land use planning suggest four developments in its concepts and practice which should characterize the future First the problem of integrating the space use consideration of urban planning and the resource use considerations of rural planning will demand increasing attention of professional planner governmental official and interested citizen Conceptual and methodological interchange and adaptation should take place between the space design orientation of the city planner and the resource capability orientation

PLA E WING STRUCTURE. *S als* SHOCK ABSORBER CORD [J E S]

Bbl g phy H G C nw y *L d g Ge De sign* 1958 B Milw tsky and F E. Cook *A lys s of La d g G ar B h* NACA Rept 1154 1953

Landing ships and craft

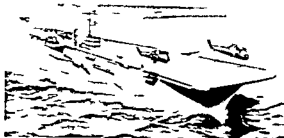
Comb t ves l employed amphibiou warf e t l d pe el a d upplie A w de ariety f l d g h p a d land g c ft ra g in ize f m m ll b t t h p e 450 ft in le gth w sed W ld W II Nea ly all wer w l p type de l ped pecially f amph b s warfare These e sel w e ge lly d g ted by th let te LS (La d g Sh p) or LC (La d g Craft) ather tha by am s Cr ft le s th n 130 ft i l gth we c d ed o ea g ing d wer t a p t d t th as a lt ar by h p A th d n ty f l d g ess l, a tru amph b an ap ble f oper t g l d a well s i w ter w also sed n W ld W II

D i g th po tw pe iod ew f t were po ted t th LSD (Land g Sh p D k) a d LST (La d g Sh p T k) by m k ng them l g r a d fa te i o der t p ed p the hea y l ft f ta k tra ked d wh led h l a d h vy m b l tr et d c mb t q ipm t

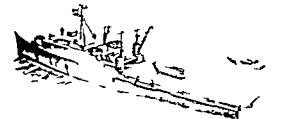
T meet the n ed of the le g d p al f h ps, a d i re i th pe d f mph b s pe t ew c n ept a d t h q a e q d Th mo t ig ifica t ew de el pm t is the use f h l pt t hurdle e nd g t b hind t gly d f ded bea h Hel pt s h e th ad d i l c p b l ty f l d g t oop q ipm t a d uppl i h p-t h e m me t t f st r t f sp d Kn wn e t l a lt th p ttern h ll d f r new typ f h ps ch a the LPH a d LPD l th ti l a lt ph e th e h p l m at th W ld W II p tt rn of the tag g f r th t fe g of t oops d q pm t f m g d pe l sh p i t m ll l d g craft

Amph b ous assault ship (LPH) The LPH i m l t m ll i c ft e h g flight deck h g r p e a d n l nd t u t f h p nd flight t l Th LPH 2 sh w F g 1 i 600 ft l g d d pl 18 000 t

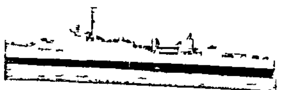
Amphibious transport dock (LPD) Th LPD l d t p q pm nt d ppl e by m f mba ked l d c ft amph b h l a d h l pt l th d gn f th h p mph wa pl l n th n pt f a mpl t f t m b l b l ed f th LPD ld epl e t p g a d l d g h p e t n type f mph b- io pe t T d i th ap d l d g f g th h p q pped w th y mp h l g d lev t Th p h l ty f b l la i g d l k a fl t g d d k p rm t l d ng aft t ter th t rn w ll fl t (th LSD) h q pm t he l d d d tly t th l d g ft Also th l d g a n d by meth d es f th h dl g f th types f g Th LPD l l F g — 510 ft l g



Fg 1 Th LPH 2 d g d to l d t p d p- pl by m f h l pt (Off l U S N y ph t g ph)



Fg 2 Th LPD-1 l d g ft t th gh th t (Off l U S N y ph t g ph)



Fg 3 Th LSD-31 d t l h l d g ft d h l d fl t g dryd k (Offi l U S N vy ph t g ph)

nd h f lll d d pl em t of j t d 14 000 t

Landing ships The LSD h th apability of p rt l bm g n like flo t ng d yd k Sm ll cr ft e t a w ll wh h e t ds lm t th f ll l th f th h p The m i f the LSD i t c rry a d l h l ded l d g craft d h cl n amphib s a lt a d to r de l m t d d ck ng d p n f m ll c ft n the f rw d a e Th LSD 31 h wn in F g 3 510 ft l g d d pl e 12 000 t n wh the well i dry

Th LST rri t k a d hi les to mb t f mph b a a lt A l ge t nk d k xt d aft f m th b w doo d p m t g t b d h ged d tl nt the be h f m b lt amp V h l al o b

Fig 1 Typical tricycle land ng gea on F8U 2 Cru sader (Chance Vo ght A craft Inc)

the ground contributing to ea e in loading and to passenger comfort and (4) at touchdown the position of the main gear aft of the center of gravity results in no ing the airplane over onto the no e gear reducing the angle of attack and reducing the possibility of the airplane s rebounding into the air

Another arrangement still used extensively is the tail wheel landing gear (Fig 2) Two main gear struts are located slightly ahead of the center of gravity well spaced laterally to provide lateral stability a third wheel is mounted on the fuse lage near the aft end of the airplane This arrange ment is usually lighter than the tricycle landing gear It suffers in comparison with a tricycle gear because of the increased problems as ociated with vision ground maneuvering and braking

Other arrangements are often used becau e of special problems as ociated with a particular de sign The bicycle landing gear used on the Boeing B 47 is an example this gear requires outriggers for lateral stability A gear of this type will usually be heavier than the more conventional type but often is attractive for over all performance Re search airplanes such as the X 2 and X 15 often use skids instead of wheels becau e ground maneu vering i less important on airplanes of this type space and temperature con iderations control the choice Helicopters and VTOL aircraft often use unconventional arrangements becau e many of the considerations for ground maneuvering are less important

Fig 2 Typ cal ta l wheel la d g gea o F4U-4 Co

Landing gear design The primary working part of any landing gear is the shock trut which supplies the force as the airplane inks toward the ground turning the flight path from one inter ecting the ground to one parallel to the ground The most efficient shock strut is the oleo-pneu matic strut (Fig 3) It operates by generating a force as oil is pushed through an orifice When the wheel of the landing gear first contacts the ground the tire deflects to stop the un prung mass of the landing gear (tire wheel brake and pi ton of the oleo) As the airplane continues to sink the pi ton in the shock strut forces oil through an orifice causing a force which changes the airplane s flight path

To obtain a better force time relation hip a metering pin is often u ed to change the orifice

Fg 3 D ag am of oleo p eumat c shock st ut

size as the shock trut strokes Air pre ure in the strut extends the gear after it is compre ed and also acts as an air sprin u pension sy tem for the airplane during taxi ng

A alternates to the ole leaf springs rubber springs and oil pring have been successfully used

To provide f r the drag load during braking and the impul i e drag load due to spin up of the wheel after init al contact strength mu t be pro vided u ually b y a drag strut If the wheel can be ca tored as a no e wheel or tail wheel i likely to be pro i i n mu t be made to pre ent himmy u ually by the u e of a himmy damper. See Air

d est mates a i tance in lett g ontracts and peri f the ork d e by th ntractors P ject u d tak by landscape archit ct i de l g p ks a d recreati n a a e l t t bd o h ghway d parkw ys and land api g f r indu tri in titution cemete ie nd rge p at estates

Training required M t land cape a ch tect e llege-tra ed p l ts Th t ai g i des de gn d g b ild ng ar h tectur (u u ll 4y e) gi ee g rveyi g b ild g a d c tructio m t r l co t est mate a d robl m l nd pe de g Co m il a d lant sci a e met m cluded

La dsc p a ch te t e is prim ly n American fes n. In E gla d m st p je t in ol g t t l d p bl dev l pment h dl d by g er d ar h te t land p g of p te ed e d th d f dec ati e pl t gs d anly d ne by the la d c p g d e The m l d pe gard i ig lly appl ed t the d g g of nat ral tic tt gs It w a school th t a in E gl d d g th etee th t ry ppo ti t th f rm o geometr d gn that d m nated l d dev l pm t befo then

Landscape nursery service Th a p al za t n f the fi ld of la d pe ch t ture The erv l m ted t m ll iv a d publ p blem t tes the dev l pm t f h m pr p rt e d m ll est t Op at s ally as ted th a n ery ha dl ll ph se f proj t from d gn pl th gh n t u t n d pl t g d upply all ce ry m t l Tra g f l dsc pe n ery ervi ally l d th b c s e pl d a ed w rk ls d pl t n e u ery man g m t rs y g d e rthw k d m co t tio f ch tructu es a t ra pools nd w ll *S* CIVIL E GI EERING [J P P]

Landslide

Th pe pt ble d wnw d sl d g o fall g f l t ly dry m f arth rock r mb t f th tw Th t m i m time e tended t c er r l t d fl wag m me t l d g rthfl w m dfl w d d b s l h All bel g t the f m ly f m s-m em t p es wh h ge f m l w soil-creep t b pt r kf ll

La d l des h b gi g ally d it t bec f b tte d t d g f th pl f ma movem t n th sh p g f th l d w pe d bec f m g t d nd f q en f l d l d p bl m e la g t d fill m d f d m pe h ghw f d tio d th r g ee i g p j t La d l des net th h ghw y d r l d f th U ted St tes d Ca d $10 000 000 a y n tru t d m t a e a d k wn b t l g ad l t l m t n i d ect l es I the ll t l g m y l es l t h ye d rectly d ectly bec u f l d l d d ma t t phes som t me w pe ut wh l il l ges.

Landsl des al o called land l p range f m low angle r th l w sl des to vertical falls S me fl wage may cc mpa y l d g for example fol lowi g i t l lippage of a wet l m ss or in th very rap d tw d p eading of the t gue of a l g ck l d r ro kf ll wh ch may s st al m t e t ely of dry r k *S* MASS WASTING

Types of landslides Ba ed n type of m ement r l t e rate a d k d f materi l invol ed l d l des ca b ep ated i t fi e mai types— l mp d b l de debr f ll r k l de and rockf ll (Fig 1)

Sl mp The d w w d lipp g of mass of rock o u c n ol d ted deb i m t g as a unit e e al s bs d ry u t hara t i ti lly with b ck w d tation n a h r zontal is p allel to the l pe i k own sl mp Mo eme t is ually rath slow d may be intermitte t di placeme t mall rel t e t the e f th m The m jor

sl mp w h rthfl w toe

d b f ll

ock l d

rockf ll

Fg 1 Typ f l d l d s.

sl p urf ce s typic lly p haped and c ca e t w d the sl p bl ck i both ert c l nd ho tal ect The m d a e t th h ad f slump may b b ke t m y t pl ke i g la ly t lted block A m h p nd l ke may f m betw e ba kwa d t lted bl k d the l ff f m wh h t des e ded Sl mp g lly re lt f m rem l f pport l w n th l pe Th may c r by t l rt fi i l de c tt ng by fl w ge e the ub q eo ly n upwa d b lgi g th fl w Sl mp mm n n t l el ff d b k d th des f t fi al t d fill

D bri l d Th typ f l nd l d i a rap d d wnw rd l d g d f rwa d ll g f u l d t d th nd r ky d l u lly w th the f rmat o of n rreg l h mmocky dep t. At the t m f m m t th mat l m t be f ly dry th m w ld t k th ha ct t f e rthfl w D b s-l de e ally th sm ll a d fte e lt f m t l r rt fi l u d tt g f a l p

carried on the main deck The LST 1173 shown in Fig 4 is 446 ft long and displaces 7800 tons

The LSM (Landing Ship Medium) is a beaching ship with an open well and a bow ramp Its design was derived from a combination of LST and LCU The LSM is 204 ft long and displaces 1095 tons

The LSMR or Landing Ship Medium (Rocket) is a conversion of the LSM The LSMR provides close in fire support with a barrage of rocket bombardment for an assault landing operation The LSMR is 204 ft long and displace 1276 tons

Landing craft The LCU or Landing Craft Utility (assault) discharges tanks mobile equipment general cargo and personnel directly onto the beach The LCU is designed for limited voyages and usually is carried to the unloading area by an LPD LSD or LST The LCU 1613 shown in Fig 5 is 135 ft long and has a combat landing displacement of 370 tons

The LCM (Landing Craft Mechanized) is used in a ship to shore operation and lands on a beach to discharge vehicles or cargo A typical LCM is 74 ft long with a maximum displacement of 127 tons and is designed to carry one heavy tank 60 tons of cargo or 200 troops

The LCPL or Landing Craft Per onnel (Lead) is a dual purpose boat for guiding other landing craft in an assault wave in a ship to shore operation The LCPL is 36 ft long and has a capacity of 4500 lb of cargo As a personnel boat it has a crew of 3 and carries 17 men

Amphibious vehicles The LVT (Landing Vehicle Tracked) is an armored amphibian It can negotiate a surf up to 15 ft high and di charge 34 men inland The LVTP 5 (Fig 6) is 30 ft long

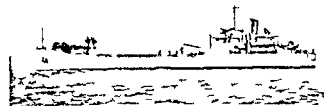


Fig 4 The LST 1173 d g d to d scha ge ta ks a d other eh cles d ctly onto a b a h (Off c al U S Na y photogr ph)



Fig 5 The LCU 1613 us d to d scharge v hi les equ pment and person el d ectly o t a b h (Off c al U.S N vy phot g aph)

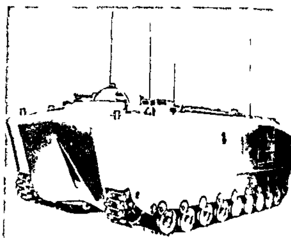


Fig 6 The LVTP 5 an a mo ed amph bian (Off al U S Na y photog aph)

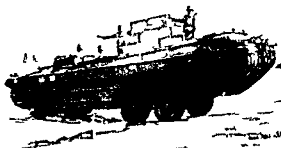


Fig 7 The DUKW de eloped for l nd ng on sandy beaches (Off c al U S S gnal Co ps phot g aph)

and has a cargo capacity of 6 ton in water or 9 ton on land

The BARC (Barge Amphibiou Re upply Cargo) is a wheeled *amphibious vehicle for over* the beach handling of cargo U ed by the U S Army it is 63 ft long and has a cargo capacity of 60 tons

The BDL IX (Beach Discharge Lighter) u ed by the U S Army carries vehicular and other types of cargo on the main deck for hip t hore landing operation When retracting from the beach it i a i ted by a hydraulically operated ram The BDL IX i 338 ft long di place 4126 tons and i capable of tran ocean voyage

The DUKW (Truck Amphibian 2½ Ton) commonly calle l duck is u ed by the U S Army to transp rt cargo or per nnel on land or water (Fig 7) It i 3(ft long and has a cargo capacity of 5175 lb S e SHIP NAVAL [H J M]

Landscape architecture

Defned by Charles Eliot one of America s fir t land cape architect as the art of arranging and fitting land f r human u e and enj yment Land cape archite ture is an applie l art f unded on the premi e that u e and beauty are compatible and that neither i c mplete with ut the otl er

Tl e er ice of the land cape arcl ite t s milar to th e of a building architect in ol e con ulta tion pr parati n of rep rts plan specification

k fun t n of th c ll ct r and emitter The nemour Ch ld l w appl s to a cl e a p ximation to ther electrod g tr es as w ll Th coa al cylind with the nner cyl nder th thod it lead t de at on f om the true v lue the current de ty f at mo t 13% See DIODE CUUM SPACE CHARGE

[E C R A]

anolin

h hyd u heep s wool fat (p m rily choles- f este s f h gher fatty a id) de ed a a by prod t fr m the prepar tion f raw wo l f r the p n The crude w l f t pur fied melted m ed ith about 30% w ter d all wed t h d t a ft p le y ll w ungu ntl ke ub-

La l w d ly u d a b e f m ll nt t p t t a d be ut fy th k d l o in t m- poo t make the ha r l b ittl and m e lus- t u It ha sl ght ant ptic ffe t a d h gh re ts e t r nc lity and it may be fo th se r so th t it has c nt nued wid e as a ba e for k n tm t Act ally lan l n h d s ab rp- t n f the med at thr ugh th k n a om p red t ther h t n e uch s l e l o lard La l n ol ble in alcohol ther hl ofo m a d be S FAT A D OIL, NONEDIBLE

[G CO]

Lantern slides

P t et p ent p ctu o gla film which ca be ewed by p j t n o t r fle t g c en o n hand e s r de s n wh ch th p t re is pr j cted o t the r r of d ff g s r en S nd d s e e Un ted States 3 by 4 B t t h, 3¼ by 3¼ C nt ent l 85 by 100 mm i t rmed at Co t tal 0 by 0 mm 2¼ by 2 m i t r (th m t p p l) 2 by 2 The l t size am d a ed e e vwher The apert re s e of the m ked pi t r s h e b en t nd rd ed Alth ugh bl k and wh t t a p e es h d be n mad n 2 by 2 n ze from m n t e m n gat in e the e l day of th t t pe f m ra th pr t r a p p la ty f th by l d a d th ppropr at proj c tor a d f d n f t the mi tur cam er itself) t ms fr m th int odu t n f K d m film d its t n fr m pro e g i the a dbo d K d k R d Mu t a th K da l d t n p r y

Sl d r pr j ted e t n l p j ctos (pt al l t n) n t g f c nt ated soot l l ght nde t m h ld (o h nge) f r th l d a p j t n le a d (u a) a bl f r ool g th sl d (s e PROJEC N SYSTEM O TICAL) T ng t n fil m t l mp gener lly w th p efoc ed b ed n w tt ges f m 150 t 1000 dep d g r n th p o- jected p t m l m attag a f h m se Th focal l gth f th l g erned by th p ject d t e d scree s e Ma y t f l l ha g r m d in l d g h nd feed g l fes at a t m a h ng r wh l c

the two sl de (on i l anged wh le the other is project d) ca tt whi h c rrie a gr up of l d and f ed lid n and out emaut mati ally and a maga ine of lide which are a oc ated with t mer a d are fed and changed f lly uto mat ally S me l olders ca ry long rolls f film nd film trip

Sl des pa ticula ly n the min atu r i e can b ewed in hand ie er or tabl iewe The forme have mea fo ill m nati g the l de po nting t t th ky r t a lamp or u ig l mp in l ded in the i wer f e l d l att r wall outlet op rat n, and a imple mag if i g len They ar mad f r gle r ter l de T ble iewe ar really m ll p oje t rs gi ng n image f m de at m gnifi at for ewi g a rea pr ject r n and ha manu l or aut mat c sl de ch nge Large d play tra sparenci (18 by 60 ft th ca e f the K lak Col ama i Grand Cent al Stat on n N w Yo k C ty) u bank of l ght gi un f rm illumination r a diffu ng screen immediately beh nd the p cture

[W C]

Lanthanide contraction

The n me g en to an unu ual ph n men n en u t red in th r e e rth e es f element The d of th at m of th memb er of thi eri de- ea lightly as the t m numbe increa es Starti g w th element 58 n the pe dic t bl the b l nc ng el tr n fill in n in er i mplete 4f h ll as th h rge n the u l in e e Ac rd g to the theory of at m t u t r thi hell n l ld 14 ele tr ns o tartin w th elem t 58 r um th re a e 14 tru r r earths La than m h n le t ns the 4f h ll m ha l a d l t t m 14 The 4f electr pl y lm t r le i h m c l ale ce all ra e e rth can ha e 3 le t s tl e r le c hell nd they all e i t a tr alent n ol tion As the cha g n the u le in rease the rare e rth s all le t n e p lled n cl er t th n l u that th rad f the r e ea th on d a sl ghtly a th mp und g r the rar e th r e A y g n mp d l th are e rth y l kely t t ll ze w th the m st ucture a a y ther e th ll we er the l ttic p ram te b me maller d the ry tal d n er a th c mp nd p d c th es This c ntra ti n of the latt ce p m te kn n tl e l nth d n t a t n F m ny mp u d the l tt p am t d ea l p rt way a r tl r es a d wh n th ntr t n h pr g e ed f r w v t ll e f m dev lop F q e tly b th ery t l l f rm c n b ob erved f numb of th l m t Fo th r n th ar th e es f p t l r i t t to e t t b ma y of th p r m t d te m n ng th p pertie f a ib t ce a be k pt ta t whil th latt p i g n b ri d i m ll i em t acr s th e ies

Th t m d io rad f at m are n t l rl d fi ed Th at m n be p l ri ed by the

Debris fall A relatively free downward or for ward falling of uncon olidated or poorly con oli dated earth or rocky debris con titutes this type Debris falls are common along undercut banks of rivers from walls of rapidly eroding gullies and in steep excavations

Rockslide This type applies to any downward and usually rapid movement of newly detached segments of the bedrock sliding on bedding or any other plane of eparation Rockslide may form wherever dipping strata or jointed rocks are inter rupted downslope by any kind of cut They include ome of the greatest of recorded landslides A rock slide in the Cros Ventre River valley of Wyoming in 1925 (Fig 2) for example displaced 50 000 000 yd^3 for a total of about 2000 ft down a dip slope of 18–21 and dammed the Gros Ventre River *See* ROCK MECHANICS

Rockfall The relatively free falling of a newly detached segment of bedrock of any ize from a cliff or steep slope i called rockfall Rockfalls are common along headwalls of glacial cirques and on wa e cut cliffs They are a constant hazard on verti cal rock cuts along transportation route where the fall of a block weighing e en a few pounds may di able a vehicle or kill its occupant Many of the world s large t land lides have been combinations of rockslide and rockfall Rockfalls into fiords and mountain lakes sometime produce enormous waves capable of demolishing waterfront villages *See* EROSION



Fig 2 Gros Vent e la dsl d of J 23 1925 h w ng scar and low pa t of sl d deb s Li coln Co ty Wyoming (USGS)

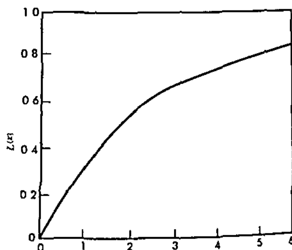
Prevention and control of landslides This de pends primarily on avoidance of unsuitable con struction in areas of old slides or recognizable mass movement hazard Other basic measures for pre ention and control include excavation to re move fallen or unstable material drainage of un stable or potentially unstable material t reduce weight and increase hear resistance and to pre vent additional water from gaining acces to dan gerously placed mas es placement of re training structure such as piling buttres es retaining walls cribbing and wire fences or netting to keep fallen rocks off communication routes Warning devices are sometimes u ed to clo e railroad blocks when fallen rocks or debris slides enter a right of way [C F S S]

Bibliography *Landslides and Engineering Prac tice* NAS NRC Publ 544 Highway Re earch Board Spec Rep 29 1958 C F S Sharpe *Landslides and Related Phenomena* 1938

Langevin function

A mathematical function which is important in the theory of paramagnetism and in the theory of the dielectric properties of insulators The analytical expression for the Langevin function di played in the accompanying figure i

$$L(x) = \coth x - 1/x$$



Plot of La g v fu ct o

If $x \ll 1$ $L(x) \cong x/3$ The paramagnetic suscepti bility of a clas ical (non quantum mechanical) col lection of magnetic dipoles is given by a Langevin function as is the polarizability of molecules hav ing a permanent electric dipole moment In the quantum mechanical treatment of paramagneti m the Langevin function is replaced by the Brillouin function For further discu ion *see* DIELECTRIC CONSTANT PARAMAGNETISM [F A F K]

Langmuir Child law

A law governing space charge limited flow of elec tron current between two plane parallel electrodes in vacuum when the emi ion elocities of the elec trons can be neglected It is often called the three halves power law and is expressed by the formula

$$j(\text{amp/cm}^2) = \frac{\epsilon}{9\pi}\left(\frac{2e}{m}\right)^{1/2}\frac{V^{3/2}}{d^2}$$
$$= 2\ 33 \times 10^{-6}\frac{V\ (\text{volts})^{3/2}}{d(\text{cm})^2}$$

Here ϵ is the dielectric con tant of vacuum $-e$ the charge of the electron m its ma V the potent al differen e between the two electr de d their epa ration and j the current den ity at the collector electrode or anode The p tential difference V is the applied oltage reduced by the difference in

The fir t and la t m mbe s of th s quati n form th fl theo m mely that the tot l flux (f l eat if istemper t r) o C is zero

If $(x y)$ i harm nic i th cl ed d k b ded by the ci umf re ce γ a d $f(\ )$ the c r j o d g analyt f n ti n, n c take th e l p rts f both membe of th eq ti exp Ca hy s tegral form la

$$_0 = \rho(\cos\theta + \ \sin\theta) \qquad d \ = \ (\ - \ _0)\, d\theta$$

$$f(_0) = \ (x\ y_0) + \ (\ \ y) = \frac{1}{2\pi i}\int \frac{f(\ )\, d}{\ - \ _0}$$

$$= \frac{1}{2}\int f(\ )\, d\theta$$

$$(\ \ y) = \frac{1}{\ }\int \ (x\,y)\, d\theta$$

Th l t qu t e pres e Ga ss m n l e theorem th t the g of $u(x\,y)$ γ is the l e t the cente of γ F m tl th o m it f l l that f n t n harm n at a point $(x\ \ y\ )$ can ot h tro g local ma imum (r min mum) he d c n h a k l cal t mum (r n m m) o ly if id t lly n ta t th o h ut t neighbo hood f $(\ _0 y\ )$ If $(x\,y)$ i h rm i n i bou ded eg n D c nt i th c re pond g cl ed reg n $\overline{D}$ the m mu a d mi m m of $(\ y)$ occu n the bou d ry of D f a ma m m mi mum occ s int ri r t D the $u(x\,y)$ d t lly c t t th gh ut D

It D i a bo nd d g n w th b und ry B d f ti l es $U(x\,y)$ a gned n B the Dirichlet pr blem the p bl m f d termin ng a unctu $(x\,y)$ harmo n D c ti uous o $+B$ eq al t $U(\ y)$ on B If D i c ula gi n a J dan r gi n r a y n path l gic l e- ion th D ri hl t p bl m h ol t ec s- a l (by th b f no tr al m m and n m int to D) I If D c la k f d s l e ll t t o) th D r hl t roblem f D sol ed by P o int g l

$$(\ \theta) = \frac{1}{\ }\int \frac{(\ \ - r^2)U(\psi)\, d\psi}{\ - \ _0 a \qquad (\theta - \psi) + r^2}$$

ng polar oord at s (θ) w th p l th t l D If D i less l m t y eg n b t w th nooth b d ry B th D hlet p blem l ed y G ee f rm la

$$(\ \ y) \quad \frac{1}{\pi}\int_B U(\xi\,\eta)\,\frac{\partial g}{\partial\ }\, d\ (\xi\,\eta)$$

he i d t tl i t la m l in th f (ren f t $g(x\,y\,\xi\,\eta)$ h rm D pt at ( ) t and η l t e d th neighborhood f $(x\,y)$ ha th f rm l $g[(\xi - \ ) + (\eta - y)\ ] + g\ (\xi\,\eta)$ h re $(\xi\,\eta)$ h m at ( ) If th bo d) B m t mooth th f m l c n be xp sed i tm f h rm m e t d f $(\partial g/\partial n)\ d$

C c l d k D of d

Num u er es expans on (for xampl F ur er ser s) can b u ed f r the ol ti f the D r hlet p blem fo a i s eg n

n Dimensional relations Tl e f going emarks pply to Lapla e quati n w th two nd p d t iabl th f cts (but n t th meth d of p oof u g a lyt c fu cti n) apply al o i th ee o m r d men ns Th s i th e d men ns p nt d t ibut of matte f ma s m t p int $(x\ y\ ,z\ )$ h a p t tal d fi ed a

$$u(x\,y\ ) = \Sigma m\ [(x - x_k) + (y - y_k) + (\ - \ )^2]^{-1/}$$

wh h i harmo xcept n the po t $(x\ y\ _k)$ E cept t s h p t t the f c (Ne tont law of gr t ti) xert d b th d tr but n n u t xpl rat y part cle at $(x\,y_k)$ ha the c m p ne ts $(\partial\ /\partial x\ \ \partial u/\partial y\ \ \partial u/\partial\ )$ d the compo- n nt f the f c in ny di ect on s the direct on l d i at of $(x\,y)$ th t d recti Se POTEN TIALS (MATHEMATIC) SPHERICAL HAR IO ICS [J L W]

Bibl og aphy O D Kellogg F nd t of Po- t t l Th o y 19 9

Laplace s irrotational motion

Lapl e eq at f rrotat n l m t n f n n d mp ble fl d is the p rt l diff en t l qu t

$$\frac{\partial\ \phi}{\partial\ _1^2} + \frac{\partial\ \phi}{\partial x_2} + \frac{\partial\ \phi}{\partial x_3^2} = 0$$

wh e x_3 re ectangul Carte n coord nat in n t rt l refe nc f ame and

$$\phi = \phi(x\ ,x\ ,x\ ,t)$$

i th elo ty pote t al The flu d l ity m po nt $u\ \ u\ \ u$ in th thr e resp t e r ct gu l r oo d n t d cti s re g by $u = \partial\phi/\partial$ = 1,2 3 M e gen all i a y inert al coo d nat s t m the qu t n i d (g d ϕ) = 0 and th elocity ect i = gr d ϕ

Atomic and Ionic radii of rare earth metals

El m nt	R I A 3+ n	Met l cry t l t t [b]	M t ll c I A	[d]
Sc		l p	1 (4	1 6 80
Y		l cp	1 8 37	1 7780
La	1 061	l p	1 88	1 8694
C	1 034	fcc	1 8 18	
P	1 013	l p	1 83(3	1 8 01
Nd	0 99	l p	1 8 90	1 8139
Pm	0 9 9			
Sm	0 9(4	l n l p	1 810	1 7943
F	0 9 0	l c	1 994	
Cd	0 938	l cp	1 8180	1 786
Tl	0 9 3	l p	1 800	1 6 6
Dy	0 908	l I	1 79	1 7 15
Ho	0 894	l cp	1 7887	1 4 8
I r	0 881	l cp	1 7794	1 7340
Tm	0 869	l p	1 7688	1 37
Yl	0 8 8	f	1 9397	
Lu	0 848	l cp	1 7 16	1 1 1

D t f om D H T mpl t l C l H D l n *J Am Ch Soc* 6 5 37 39 19 4

[b] D t f m F H Sp d l ng A H D n an l K W He rm nn 4 *l C y t* 9(7) 9 563 19 6 l cp l e gon l lo p ck l f f t l c l c h m rl ml c b c, l ody t rc l l

D t f m K W H m n D t l tl d l l t d f m t m l l I l

[d] D t f om K W H m D t l tl l b tw l y rs

neighboring atoms and there is no clear cut boundary between the electrons associated with one atom and another Therefore the atomic radii will vary omewhat from compound to compound and the absolute values depend on the method of calculation However if most of the parameters are assumed con tant and the difference in lattice parameters in the rare earth crystalline eries is attributed to the rare earth ion or atom then the lanthanide contraction becomes clearly evident Although scandium and yttrium are not members of thi eries the information is usually wanted at the ame time and is given for completenes The atomic radii of the trivalent ion and the metal atom are given in the accompanying table *See* PERIODIC TABLE RARE EARTH ELEMENTS [F H SP]

Lanthanum

Element number 57 lanthanum La is a metallic element that is the econd mo t abundant of the rare earth group Its atomic weight is 138 92 and the naturally occurring element is made up of the stable i otopes La 0 089 and La 99 91 It was discovered in 1839 by C C Mo ander It occurs a sociated with other rare earths in monazite bastna ite and other minerals It is one of the radioactive products of the fis ion of uranium thorium or plutonium It is the mo t ba ic of the rare earths and can be separated rapidly from other members of the rare earth eries by fractional crystallization Con iderable quantitie of it are eparated commercially ince it is an important ingredient in glass manufacture Lanthanum imparts a high refractive index to the gla s and it is used in the manufacture of expensive len es The metal is readily attacked in air and i rapidl converted to a white powder For other properties of the metal *see* RARE EARTH ELEMENTS

Lanthanum becomes a superconductor below 5 K in both crystallization modification hexagonal or face centered cubic [F H P]

Laplace s differential equation

Laplace s equation in two independent variables x and y is

$$\frac{\partial^2 u(x,y)}{\partial x^2} + \frac{\partial^2 u(x,y)}{\partial y^2} = 0$$

and is of central importance in both pure mathematics and mathematical physics A function $u(x,y)$ having continuous first and econd partial derivatives and atisfying Laplace s equation in a neighborhood of a point is called harmonic at that point If a plane piece of tinfoil has it edge kept at a temperature which varies from point to point but does not change with time and if the flow of heat in the tinfoil is steady (that i independent of the time) the temperature $u(x,y)$ at interi r point of the foil i harmonic Likewi e Laplace equation d minate the flow of electricity (the potential is similarly harmonic) and the flow of any inc m pre il le fluid

Two dimensional relations If $f(z) = u(x,y) + iv(x,y)$ is an analytic function $u(x,y)$ and $v(x,y)$ are conjugate function and are harmonic (*see* COMPLEX NUMBERS AND COMPLEX VARIABLES) Conver ely if $u(x,y)$ i harmonic in a simply connected region D one may et

$$v(x,y) = \int_{(x_0,y_0)}^{(x,y)} \left(-\frac{\partial u}{\partial y}\,dx + \frac{\partial u}{\partial x}\,dy \right)$$

where (x_0,y_0) i fixed in D and (x,y) arbitrary in D It follow from Green th e rem th at th e integral over a path in D i independent of the path so $v(x,y)$ is uniquely define l through ut D the function $u(x,y)$ and $v(x,y)$ are conjugate in D and $f(z) = u + iv$ i analytic there Under the e c n dition let C now l e a regular Jordan cur e in D if n lenotes th e interior n rmal of C the equati n $\partial u/\partial n = -\partial v/\partial s$ f llow fr m the Cauchy Riemann quation whence

$$\int_C \frac{\partial u}{\partial n}\,ds = -\int_C \frac{\partial v}{\partial s}\,ds = -v(x,y)\Big|_C = 0$$

Th first d la t m mbe s of th e ι ι ti f rm ι flux theo em mely that the total flux (f l at if is tempe at) o er C zer

If $u(x\ y)$ ι harm c in th cl ed d k bounded by the ircumf e c y a d $f($) the c r p l ng anal ti f cti n e ca take the r al ι rt f both member f the q at x ι es ι g Ca hy ι t g al f rm la

$$-_{0} = \rho(\cos\theta + \iota\ \ n\ \theta) \qquad d\ = \iota(\ -\ _{0})\ d\theta$$

$$f(_{0}) = (\ \ y_0) + \ (\ \ ) = \frac{1}{\pi\iota}\int \frac{f(\ )\ d}{-}$$

$$= \frac{1}{\pi}\int f(\ )\ d\theta$$

$$(\ \ ) = \frac{1}{\pi}\int (\ \ )\ d\theta$$

Th l t eq t n xp es es G me al e theorem, th t th a erag f (x) er y ι th al t the ce t r f y F m th theor m t f l lo s th t a fu t h rmo c t po nt (y) anoth a e t ng loc l ma m m (or mi im m) th re a d n ha w ak local m xim m (mi m m) ly f de t lly n t nt th ugh t n ghbo hood f $(x_0, y\ )$ If $u($ y) h m ic n a bou ded egi n D co t ι th rrespo d ing losed eg n $\overline{D}$ the m im m a d mi m m f $u($) oc u th bo nd ry f D if m x m m mi m m oc ι t ri t D th $(x\ y)$ id tically con tant thr gh ut D

If D is bo ded reg with bou d ry B nd if co tinu l e $U(x\,y)$ a g ed o B the Dirichlet probl m th pr bl m of d term ni g a fun ti n (y) harm ι D tinu n $D+B$ equ l t $U($ y) n B If D ι a ι ul regi n, J rd r a y n p th l gic l e g n, the D hlet probl m h a soluti neces-sarily (b th b e f t l m m a d minima ι t r t D) n q e If D ir ul di k f d u (see ll t t n) the D hl t probl m f r D l d by P son teg al

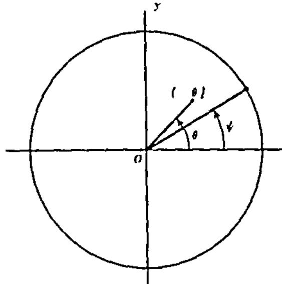
$$(\ ,\theta) = \frac{1}{\ }\int_0^{2\pi} \frac{(\ \ - r^2)U(\psi)\ d\psi}{-\ \ _{0}a\ \ \ \ (\theta-\psi) + r^2}$$

g pol oo d n te (θ) with pole th c t ι D If D a les l m t ry gio b t w th mooth bo d ry B th D hl t p bl m l d by G een f rm l

$$(\ \ ) = \frac{1}{\pi}\int U(\xi\ \eta)\frac{\partial g}{\partial}\ ds(\xi\ \eta)$$

h re d tes th ι o n m l n th f mula.

Gree f t $g($ $\xi\ \eta)$ h rm D cept ι ( ) t u d q l t r o B and in th ghborhood of (y) h th f rm ι l g $[(\xi - x)\ + (\eta - y)\ ] + g\ (\xi\ \eta)$ wh e $g\ (\xi\ \eta)$ is h rm ni t $(x\,y)$ If th b und ry B is t mooth, th f rm l be p ed ι t rms (h rm mea in t ad f $(\partial g/\partial\ )\ d$



C lo d k D f d

Num r ie xp n n (f r mpl F ur er series) ca be used f r tl sol it n f th Dir hl t pr ll m f r a ι r g n

n Dimensional relations Tl f g g rema k p ly t Lapl c ι t n w tl tw n l pe l nt ι bles th f t (l it n t tl n tl l f proof ng alyt fu t on) apply also ι tl ree r m re d m n n Th ι tl r e d m ι ns, a poi t d t ilut n l m tt r l m es m at ι ι t $(x\ y\ _0)$ h a pot ti l defi ed

$$u(x\ y\ \ ) = \ _m\ [(\ -\ \ )^2 + (y - y\ )^2 + (\ -\ \ )]^{-1}$$

wh h harm n c xcept in the ι nt (x) Exc pt t u h point the f c (N wt nia law f gr it t n) e erte l l y tl di tr lut n n a unit plo t ry pa ti l t $(x\,y_0)$ h th c m pon t $(\partial\ \partial\ \ \partial u/\partial y\ \ \partial u\ \partial\ )$ d th mpo-ne t f th fo e n ny d ect n ι the d re t nal d r ti e f (y) ι th t d recti n S POTE TI LS (MATHEMATICS) SPHERICAL HAR ONICS [J L W]

B bl g phy O D Kell gg *F dat of l o t t l The y* 1929

Laplace s irrotational motion

Lapl e q t f ι rt t n l m t f an d ι mp es ibl fl id th parti l d ff ren t l q t n

$$\frac{\partial\ \phi}{\partial x} + \frac{\partial\ \phi}{\partial} + \frac{\partial\ \phi}{\partial x} = 0$$

h r x x re tang l r Cart n coordi-tes n intert l ref nc f am and

$$\phi = \phi(x\ ,x\ ,x\ \ t)$$

th el ty p tent l Th fl d eloc ty c m p e t u the three r pecti e ctangu l d t d t a gi n by $= \partial\phi/\partial$ $= 1,\ 3$ M ge e ll in any n rtial oordi nate y t m th qu t d (g d ϕ) = 0 and th l ty ct ι v = g ad ϕ

omic and ionic radii of rare earth metals

Γl m t	R l u A 3+ n	M t l c ystal t t ctur [b]	Met ll ra l t A	
				d
Sc		1 p	1 6 t	1 6 80
Y		1 1	1 8 37	1 7780
I	1 061	1 cp	1 88	1 8691
Ce	1 031	f	1 8 48	
I r	1 013	1 cp	1 8363	1 8 01
Nd	0 99	1 p	1 8 90	1 8139
I m	0 9 9			
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Γ	0 9 0	bc	1 991	
Cd	0 938	1 1	1 8180	1 86
Tb	0 9 3	1 cp	1 800	1 7(6
Dy	0 908	1 1	1 79	1 7 1
H	0 891	1 p	1 88	1 71 8
Γ	0 881	1 p	1 7794	1 7340
Tm	0 8(9	h p	1 7688	1 7 37
Yb	0 8 8	f c	1 9397	
Li	0 848	hcp	1 7 16	1 7171

D ta f D H T ıl t l C l H D ul n J 1m Cl Soc 6 37 39 19 1

[b] D ta f m F H Sp l l g A H Da n l K W H m nn 1 / Cry t 9(7) 9 (3 19 6 l cp h g l lo ı k l fc f nt l l l om l oml bc l o ly t l c l

Dat f m K W H m n D t al th l l t l f m t m l l pl n l

[d] Data f m K W H n D to al th l be twe n l ye

neighboring atoms and there is no clear cut boundary between the electrons associated with one atom and another Therefore the atomic radii will vary somewhat from compound to compound and the absolute values depend on the method of calculation However if most of the parameters are assumed constant and the difference in lattice parameters in the rare earth crystalline series is attributed to the rare earth ion or atom then the lanthanide contraction becomes clearly evident Although scandium and yttrium are not members of this series the information is usually wanted at the same time and is given for completeness The atomic radii of the trivalent ion and the metal atoms are given in the accompanying table *See* PERIODIC TABLE RARE EARTH ELEMENTS [F H SI]

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where $(x\ y)$ is fixed in D and $(x\ y)$ arbitrary in D It follows from Green s theorem that the integral over a path in D is independent of the path so $v(x\ y)$ is uniquely defined throughout D the functions $u(x\ y)$ and $v(x\ y)$ are conjugate in D and $f(z) = u + iv$ is analytic there Under the conditions let C now be a regular Jordan curve in D if n denotes the interior normal of C the equation $\partial u/\partial n = -\partial v/\partial s$ follows from the Cauchy Riemann equations whence

$$\int_C \frac{\partial}{\partial n}\, ds = -\int_C \frac{\partial}{\partial s}\, d = -v(x\ y)\Big|_C = 0$$

l u n $\phi(t)$ f m th g er ting f ct n $f(s)$ Thi i e pecı ll tru wh n tal le a u a a lal le r m deq te Any p es n f $\phi(t)$ ı t rm f $f(\ )$ ı lled an ın r n f rm la (se INTEGRAL T A FORM) Ma y a kn wn Th la al e t

$$\phi(t) \quad \frac{1}{\pi i}\int_{\infty}^{\infty} f(\ )e^{\ } d \qquad 0 < t < \infty \quad (1)$$

H the ntegr t ı l ng n l e $\sigma =$ f tl compl s pla e wh h the nteg al (1) ges absol t ly A th r wh l mpl y th r l bl nl ı

$$\phi(t) = \lim_{k\to\infty} \frac{(-1)^k}{k!} f^{(k} \left(\frac{k}{t}\right)\left(\frac{k}{t}\right)^{k+1} \qquad 0 < t < \infty \quad (5)$$

Here $f^{k}(\ )$ m an the $k$tl d r ati f $f(x)$ Equ ti (5) I ll trated I th mpl A ω F r th t p $f^{k}(x)$ e tly mp ted and Eq (5) bec m

$$e^{\ } = \lim_{k\to\infty}\left(1 - \frac{at}{k}\right)^{-k \ 1}$$

famil ar result I l l

Generalizations Cert g n r l zat n of Eq (1) ar n f qu nt Th t n f rm

$$f(\ ) = \int_{-\infty}^{\infty} e^{-\ } \phi(t)\, dt \qquad (6)$$

ı lled th b l t ral Lapl e t f rm A i ers o till p ded by Eq (4) wh h n w h ld f $-\infty < t < \infty$ If n set $= iy$ Fq (6) the result

$$g(y) = f(\ y) = \int_{-\infty}^{\infty} - \ \phi(t)\, dt$$

This equ t d fi es $g(y)$ the F r t a s f rm f $\phi(t)$ Th t the Lapl e t f rm (6) ıf d ed l g gl l be mes F n t f m. By tt g $= 0$ and $s = y$ f r m la (4) bt

$$\phi(\ ) = \frac{1}{2\pi}\int_{\infty}^{\infty} f(\ )e^{\ } d = \frac{1}{\pi}\int_{-\infty}^{\infty} g(y) \quad dy$$

th l l f th F ri tr f rm

A th g r l zat of Eq (1) ı th La pl St ltjes nt g l

$$f(\ ) = \int^{\infty} - \ d\alpha(t) \qquad (7)$$

wh e n w the t gr l St ltj tegr l w th esp t t th t g at f t n $\alpha(t)$ If $\alpha(t)$ h d at e $\phi(t)$ th tegr l (7) b mes (1) On the th h nd f $\alpha(t)$ t p-fu t Eq (7) ed t Di ll t ıes

$$f(\ ) = \sum_{\ }^{\infty} \quad - \mu$$

t pe f l gr t mport n t al t numb theory

It m t t h ppo ed that o e m y hoo $\phi(t)$ o $f(\ )$ b t l Fq (1) nd p t t m t t ı L F x mpl f $\phi(t) =$ the t gr l (1) d ges f all s d $\sigma = +\infty$ Aga ıf $f(s) = s$ n c rrespond ng d t mi ng fu t n $\phi(t)$ xi t n it ı l n tl at r g rating f t n m t appr ach limit a $s \to +\infty$ l ng th r al ı H n e it ı l l import t to kn w wh t f in t $\phi(t)$ and $f(s)$ may be u ed in Fq (1) S f r a $\phi(t)$ cr ned tl p l l m c mpl t ly sol ed l y tl f rm il with $\sigma > 0$

$$\sigma = \overline{\lim_{t\to\infty}} \frac{l\ g\,|\alpha(t)|}{t}$$

Tl tf r p ll m ha been part all sl ed l y r p- res ntati theo m f r ı t gr l tr f m ne triki g ampl f wh h ı pres ted lel w

A f n t $f(\ )$ f th r al ri ll s ı ail t be mpl t ly m t n $< s < \infty$ ıf and l f

$$f(s) \geq 0 \quad f'(s) \leq 0 \quad f\ (s) \geq 0$$
$$f\ (s) \leq 0 \qquad (\ < s < \infty)$$

F mples r $f(\ ) = 1$ $f(s) = 1/(\ -a)$ a d $f(s) =$ A theor m f S B r t tates that $f(\ )$ ha r p ese tati n (7) c n g g f r $>$ d with ı t g t r f t $\alpha(t)$ der g ıf a d nly ıf $f(\ )$ mpl tely m t n f r $a < \ < \infty$ F r e mpl ıf $f(\ ) = 1$ th n $\alpha(t) = 1$ $t > 0$ $\alpha(0) = 0$ ıf $f(s) = 1/(\ -a)$ th n $\phi(t) = e^{\ }$ and $\alpha(t) = (e^{\ } - 1)/$ ıf $f(s) = e^{\ }$ $\alpha(t) = 0$ f r $0 < t < 1$ d $\alpha(t) = 1$ f r $1 < t < \infty$ In ea h c $\alpha(t)$ n decr a g pred ted l y B rn t theo m Tl esult ı p rt ul ly re- m rkal l becau th m r ıgn f the rres v der ati es l f ti n n th r al xi d r m n t nly ıt h l m ph h ra t r (pr pe ty II bo) ın half pl e but also ıt rep esent ti th f rm f Fq (7) [D V W]

Bibl g phy A Erd ly (ed) *Tabl s f Int g al T nsf ms* l l 19 4 I S Lapla *Th o ı nalyt q d p b b l tes* 1820 D V W d d *Th L pl T sf m* 1941

Laplacian

Th d ff r t l p r t r $\partial\ /\partial\ + \partial\ /\partial y\ + \partial\ /\partial$ ı wh h the ymbol d t th al les f ect gul r tes a oordi at y tem The Lapl n freq tly den ted by th mbol ∇ (r l d l q ar) n a rd c w th the fa t that th Lapl f ala f ct n $S(\ )$ ı th d g e of th gr d e t f S th t

$$S/\partial\ + \partial\ S/\partial y\ + \partial\ S/\partial z = \nabla \cdot (\nabla S)$$

The Lapl c pe tor ın l ed ı som f the m t fu dam t l q t n f m th m t al phy ı mely Lapl e q ti n $\nabla\ = 0$ P ← so q t o u w q t n (th se f lect ty a d m g et m sou d vibr t n th Sch od ng r q t f q a tum mech n cs) th h t fl w d dff v ty q t S CALCULUS OF VECTO S GAUSS THEOREM GRAD ENT OF A SCALAR GR EN THEORE I [H V C.]

Irrotational motion implies that the fluid particles translate without rotation (like the cars on a ferris wheel) and is stated mathematically by saying curl v = 0 where v = v(r t) is the velocity vector r is the position vector of a particular point in the fluid flow and t is the time If the fluid motion is at any time irrotational it will stay irrotational (*see* KELVIN'S CIRCULATION THEOREM) Thus any motion starting from rest will be irrotational If curl v = 0 then v may be written as grad ϕ because curl (grad ϕ) is identically zero For an incompressible fluid the continuity equation (*see* FLUID FLOW PRINCIPLES) is div v = 0 hence combining this relation with irrotationality gives Laplace's equation div (grad ϕ) = 0

The velocity field v(r t) in a certain region is determined by Laplace's equation with a boundary condition given on the entire surface surrounding the region The two most common boundary conditions are those at a solid surface and at a free surface At a solid surface the fluid velocity normal to the surface must match the velocity of the surface normal to itself v n = v n that is $\partial\phi/\partial n$ = v n is given on the boundary At a free surface such as one occurring between two fluids of different density the pressure must be continuous this boundary condition in general involves the use of the nonstationary Bernoulli equation and usually leads to wave motion *See* BERNOULLI'S THEOREM WAVE MOTION IN FLUIDS [A E BR]

Laplace transform

An integral transform extensively used by P S Laplace in the theory of probability In simplest form it is

$$f(s) = \int_0^\infty e^{-st}\phi(t)\,dt \qquad (1)$$

It is thought of as transforming the determining function $\phi(t)$ into the generating function $f(s)$ The variable t is real the variable s may be real or complex $s = \sigma + i\tau$ As an example if $\phi(t) = 1$ the integral converges for $\sigma > 0$ diverges for $\sigma \leqq 0$ and $f(s) = 1/s$

The Laplace transform is used for the solution of differential and difference equations for the *evaluation of* definite integrals and in many branches of abstract mathematics (functional analysis operational calculus and analytic number theory)

Method Extensive tables of Laplace transforms exist and these are used as any table of integrals To illustrate how a differential equation may be solved two excerpts from such a table can be used

A	$f(s) = 1/(s-a)$	$\phi(t) = e^{at}$
B	$f(s) = 1/(s^2+1)$	$\phi(t) = \sin t$

Suppose it is required to find a solution $y(t)$ of

$$y''(t) + y(t) = 2e^t \qquad \left(y'' = \frac{d^2y}{dt^2}\ y' = \frac{dy}{dt}\right) \quad (2)$$

such that $y(0) = 1$ $y'(0) = 2$ Denote the Laplace transform of the unknown function $y(t)$ by $Y(s)$ Integration by parts gives

$$\int_0^\infty e^{-st}y''(t)\,dt = -y'(0) - y(0)s + s^2\int_0^\infty e^{-st}y(t)\,dt$$
$$= -2 - s + s^2Y(s)$$

on the assumption that the integrated part is zero at $t = \infty$ Applying the Laplace transform to Eq (2) and using A for the right hand side one obtains

$$-2 - s + s^2Y(s) + Y(s) = \frac{2}{s-1}$$

The differential equation has become an algebraic one whose solution is

$$Y(s) = \frac{1}{s-1} + \frac{1}{s^2+1} \qquad (3)$$

However a further use of the table shows that the Laplace transform of $y(t) = e^t + \sin t$ is precisely the right hand side of Eq (3) Assuming uniqueness one has thus obtained the required solution Because its properties can *be checked directly* the unproved assumptions need not be verified

This example illustrates the general method The unknown function is taken as the determining function and the Laplace transform is applied to the differential (or difference) equation There results an equation with the generating function as unknown and this must be solved Finally the determining function must be determined *from the generating* function either from table or by use of an inversion formula In general if the original differential equation is partial in any number of independent variables one application of the Laplace transform reduces the number of these variables by one If the equation was ordinary (one independent variable) the transformed equation is algebraic as in the above example

Properties Here are the fundamental properties of the Laplace transform

I There exists a number σ_c (perhaps $+\infty$ or $-\infty$) called the abscissa of convergence such that the integral in Eq (1) converges for $\sigma > \sigma_c$ diverges for $\sigma < \sigma_c$ That is the region of convergence is a half plane (a half line if s is real)

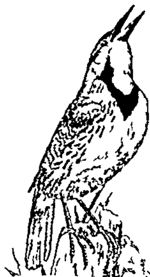
II The generating function is holomorphic for $\sigma > \sigma_c$

III The determining function is uniquely determined by the generating function (Ambiguity is possible only on sets of measure zero)

IV The product of two generating functions is in general a generating function Thus if Eq (1) holds for two pairs of functions $f_1(s)$ $\phi_1(t)$ and $f_2(s)$ $\phi_2(t)$ then the product $f_1(s)f_2(s)$ is *the transform of the convolution*

$$\phi_1(t) * \phi_2(t) = \int_0^t \phi_1(u)\phi_2(t-u)\,du$$

As was evident in the above example it is very important to be able to derive the determining



Th d w l k St H m g l gth t 11 t (From E L P lm F ldb k f N t of H st ry McG -H ll 1949)

mt th Un ted St tes m ny t me d n t tro- d t n rv ed Lo g l la d f m re tha 70 yea At p t th ly kn wn ol ny f k y l k in N rth Am i is n N n I l nd B t h Col mb

Horned lark Thi b d *E m ph la lpe tris* of th family Alaud da i rep e nted l y um o bspec s It h pe h p th w d t n tural r nge of y so gbird b ng f u d i Eu p A N rth Afric and So th Ame s well t North Am ri It i a d k br wn t s ndy col red b d th par f m ll bl k ea t ft The f h d heek tr p a d b d tl l rat are lso bl k The thro t a e f m wh t t y ll w Th ut t l feath are bla k th be t fi ld mark fl ght The h d la k i a b d f the pe try d pp ently eq me bar g d t th D g th m t g eason th mal f q tly ng ge in em k ble rti cal fl ght ng n a it cl mb and te mi t g i a breath t k g d e t pull p nruffled l d o ock h fo ts m te H ed l rk g gate i l g flock d ring th w t S e PASS RIFOR IES ROBI

[J D B]

Larmor precession

A p eces ion f the m t of harged part le i a m gn tic field (PRECESS O) The La m theo m (J Larm 1897) t t that f l t n m ng ngl tr l fi ld f f r th mot o in a u f rm magn t fi ld H t fi t rd i H th am a pos ble m t n i th ab e f H pt f the pe po t f mm p e s of g l r f q n y

$$= -H/2m \qquad (1)$$

he e /c the magn t de l th l t n ha ge l t m gn t u t d m th el t ic m The f qu y ω_L i all d th Larm f q n y a d t n m ri cally eq ial t r tim 1 40 Me p r er ted

The Larm r theor m i d rived in num rou text F r tl e peci l ca f an elect n movi g in cir lar l t f radiu r al ut a f xed nucl i w th H pp l ed n rm l t the plane f th orbit the d ri ati i f ll w tl e trip tal f r h ldi g tl lectr n in tl it m i t j l $n\omega r$ a l i tle im f th Co l ml f rce Z / and th Lor ntz forc $-(/c)\omega rH$ Tl ref r

$$\omega = \pm[(H/m)^2 + (Ze^2/mr^3)]^{1/2} - (H/m)$$
$$= \pm(\omega_L^2 + \omega^2)^{1/2} + \omega_L \qquad ( )$$

wh ω_0 i tl ngular frequ ncy in the al ence of H If $\omega_0 \gg \omega_L$ (boun l electron and f r t r l r in H) th appr im te g lar frequ y

$$\omega = \pm\omega_0 + \omega_L \qquad (3)$$

wh l i tl Larm r theor m F a free r t n l u d elect (n C l ml for) tl appr xi m t l ak d wn l t d rect sol ti n l the equ t n i l ing $m\omega r$ a d the L re tz f rc ld $\omega = -H\,me$ Th i i twi e tl Larm r fre q e cy nd i called tl e y l tr n frequ ncy S I RTI LE AC ELERATOR

I t ti g tl Larm ther em u wa made f tl pl a po l le m ti If H i applied ff ntly l wly it an be j ed tl at tl e m ti n i tl me a in th al nc f H except f r the ij p it n f tl Larm r preces H wever dd n ppl ti n f H m y ha g f exam pl la rl t int n ell ptic l n

F r a important ppl cat n f th Larm r theor m s DIAMAG ETI l ls ELECTRO TOTI N IN VACUL I

[E A F K]

B bl g aphy G Joo *Th o t l Physi s* 3d d 1958

Larnite

A rar n s l at m n ral w th mpo ti Ca_2SiO_4 wh i h w r g ally de cril ed in 1929 f m Scawt Hill C ty Antr m Ir l nd Well f rmed t l h tl n l rved l ut tl e pr nc of tw mutu lly p p dicula l a ges w th poly nth ti tw n g p r llel t n of th m nd c te m n l symm try Three art fi l cal m j t s f thi same c mp t n ar des g ated a α β nd γ Lar t prob bly re po d t o Ca_2SiO_4 T n f rmat n t the γ pha may l e p o- du d by heating by hock At Sca t H ll larn te i tim tely a ated with pur it mel l te m w t d p l i a l m t onta t z e It ha l be d cr b d fr m Cre tm e n ar R r d Cal f a S SILICATE MI ERALS

[C.S HU]

Larvacea

A la s f the ubphyl m Tun ata con ting of m n t pla kto c n m l wh h the ta l w th d r al n rv o d a d n tochord p r st thr ugh t l fe Two g ll l t r omm ly pre ent but n t m lack ng Th ep d m of the te ior r g ec t s gelat u tun wh ch i m

Lapping

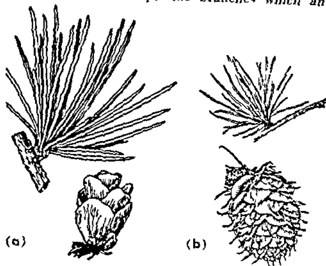
A precision abrading process u ed to bring a sur face to a desired state of refinement or dimen ional tolerance by removal of an extremely small amount of material Lapping is accomplished by abrading a surface with a fine abrasive grit rubbed about it in a random manner Usually less than 0 0005 in of stock is removed

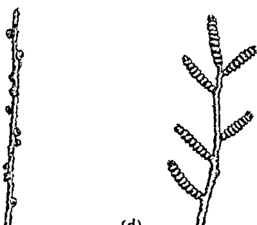
A loose unbonded grit is used It is traver ed about with a mating piece or lap of a somewhat softer material than the workpiece The unbonded grit is mixed with a vehicle such as oil grease or soap and water compound When a bonded grit is used it may be in the form of a bonded abrasive lap or a charged lap such as cast iron or copper with the lapping compound embedded in it In some cases abra ive covered paper laps are used

Although some lapping is done by hand most production work is done on a lapping machine Various type of machines are designed for work on flat cylindrical and spherical urfaces See GRINDING MACHINING OPERATIONS [A T]

Larch

A genus *Larix* of the pine family with deciduous needles and hort spurlike branches which an nually bear a crown of needles Th cones are ma and persi tent varying by pecies in ize numbe and form of the cone scales The tamarack *L lar cina* al o called hackmatack is a native pecie has erect narrowly pyramidal habit and grow in wet and moi t oil in the northea tern Unite States west to the Lake state and acro Canad to Alaska The cones are ½–¾ in long Th tougl resinous wood is durable in contact with the oi and is used for railroad ties posts sill and boats Other u es include the manufacture of excel ior cabinet work interior fini h and utility pole





(a) Tamarack La i la c na (USDA) (b) We te n larch L occ d ntal s (USDA) (c) E opean la ch L dec dua (d) Golden larch Pseudolar am b l s (A H G a es Illustrat d G de to Tr es a d Sh ub Ha pe 1956)

The western larch *L occidentalis* the mo t im portant and large t of all the specie grows in the northwestern United States and outhea tern Brit ish Columbia The cones of this pecie are larger 1–1½ in long with bracts growing out beyond the cone cales The trunk is tall and erect ometime attaining a height of 200 ft and a diameter of 6–ft The western larch has an e timated tand of 20 000 000 000–30 000 000 000 board ft mo tly in the national forests The annual production of the lumber u ually ranges from 200 000 000 to 300 000 000 board ft More than one half of the production comes from Montana the remaind r from Idaho Wa hington and Oregon

The European larch *L decidua* has cone about twice the ize of tho e of the tamarack and 40-50 scales to a cone whereas tamarack has only 1? 15 The European larch does better in drier oil and i the species usually planted in parks and private grounds

Golden larch *Pseudolarix amabilis* from China is occasionally cultivated Its leave al o d cidu ou are golden yellow in the fall The cone cales fall off one by one leaving the central axis of the cone on the tree See FOREST AND FORESTRY TREE. [A H C]

Lark

Any of a group of birds the be t known are the m adowlark the skylark and the horned lark

Meadowlark This is either of two pecies of American bird of the genus *Sturnella* family Icteridae The meadowlark is larger than a robin toutly built brown treaked above with a bright yellow breast cros ed by a black bib The outer tail feathers are white and are prominent in flight Darker than the western meadowlark *S neglecta* the eastern meadowlark *S magna* is more com monly di tingui hed by song than by color The song of the we tern pecies i di tinctly different and more melodious than that of the ea tern spe cie The range of the two pecies broadly overlap in the Mi is ippi Valley

Skylark A Europ an songbird *Alau la arve s s* of the family Alaudidae i famed for its parkling aerial ong The skylark is a dull br wn bird not prominently marked but readily di tingui hed from the h rned lark by the pre ence of white uter tail feath rs Like oth er larks it i a bird of the op en barren ground and i terre trial in it habit

The natural range of th skylark include m t of Eur pe and N rth Afri introd ced

Latent image

An in i ble imag p oduced by a ph y i l or ch m al effect f light on the di id l cry tal (u u ally l r hal d) f phot g aphi emul ion Thi im ge n be r ndered v ble by the proce kn wn a d vel pment Fo detail f lat nt image f rma n a d de elopme t s e PHOTOGRAPHY PHOTOLYSIS (PHOTOCHEMISTRY) [K W P]

Laterite

Th am g e by F B h nan (180) to the ir n rich th ring produ t of l alt in s thern In dia. The t rm t ow u ed a c mp ti nal sense f w the ng prod t c mpo ed pr cip lly f th o des a d hydrous o ides of r n al im n im tita m d manga es Ir n r h r f rr gi l t rite i l g ly h mat te Fe O and goetl t HFeO d may be an re f iron a d ckel (Cub New Caled a) Alumi u late ite is com posed f g bb te d boehm t a d i th pr i pal re of lum n m (s e BAUXITE) Cl y m n al f the k ol n gr p are typ lly a sociated with a d r g t ally r l ted to l te te Lat it ang from soft, earthy porou mat i l t ha d dense rock Concret ry forms f ryi g ze d h pe c mm ly are dev l ped Tl l r de pend on the o tent f t n x de nd ra g from b te t d rk ed r b w c mm l a te gated S CLAY MINERALS KAOLINITE WEATHERING PROCE ES

Origin Lat rite i f rm d by w athe ng u d r co d t th t l ad t the em l f li a lkal es, d alk l e e rth Th res lt ng tr n of i a d l m um o des h pl d f f e tat l te t zat from t mp rate l mate weatheri g wh ch the d prod ct i la gel l y min ral (h dro lum m s l c tes) F rly w k r f om t mpe ate r g o c n d d f te t zat n as pr f n l l ach g (des l t) n stag b yo d rd ry kaol zat n tud es i tr p l gions howe h w th t w atheri g of alk l e l c t m y y ld g bb it d ectly w th t p g th o gh nt rmed t f y tag In estigat in many pa t f the w ld tr ertai g et f t A t p cal t bt op l limate w h h gh temp atu d b ndant a f ll se so al at l a t w th p d f m k d dry es f dam t l Rel f ffic ent to n u g od dra g i eq t l t t ls a p rm bl nd d t d by h t wa h l k l y or hale. Al m u l t it f m b th w t table a d may g de t l y d pth It m y be f nd n h ll d w ll-d d l p b t th du l d pos ts dj e t alley lly k lin

Parent materials Th p r nt m t l t ol gr tly fl en th c mp t n f l t te wh h ma be dev l ped fr m ri ty f ign u m tam phic d ed m t ry r k I h k (p d tic) y ld l m n r k (t) p od bau t wh s de te b lt g t rmed at p od t Commo ly tex tural d tru tural f t e f the pare t mat ri l are pres rv d and th m re re i t nt insol ble m r l rema n

Mat re l t rit soil l ck f rtility f r m t sy t m f agr ulture Sa na r park l ke gr land ar typical n laterit Clay n t l t rit s f und beneath r nf re t an l jungl veg tat n S e VEGETATION ZONE [C]

Bibl g aphy S e BAUXITE

Lathe

A machine f r the r m l f m tal fr m a w rk pi ly gripping it e curely in a h olding dev a d r t ting it und r pow r again t a ital l cutt g tool The tool m y be m ed ra lially r l git d n lly in re pect t the t rn ng x f th w rkpie th er ma ually l atta hed pow r F rm icl a n pl res a l r latel n tr c h ped w kp eces a well a tr al d r an be turned n a l th M h ning p at s h a fa ing l i g and thr ad ng whi h re v i t n of the tur ing proce an al l e per f med n a l tl

Turn g quipme t may be cla ed a be ng e ther f th h riz tal r rt al type ref rr ng t tl turni g ax f th e w rkp ec in th ma h Tl l a eng ne latl i p im r ly a m n ally per ted ma h Fill g th g p bet ee tl n gin latl e a d f lly a t matic tu n ng eq ipm t i th tur t lath Fa t nd l t ated t h gl q nt ty produ ti n i th aut m t crew ma h

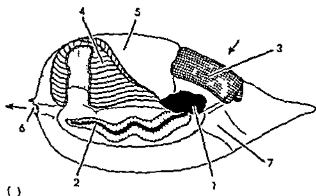
Engine lathe The tile engi e lathe r nge i i nd design fr m mall be ch and peed l the t l ge floor t p The w kp ec m y be held between tapered c nt s a d r tated w th the p we pi dle l y me f a clampi g dev r it ma be h ld i a h ck e n fixed to a r t ting pl te Wh n th w rk wu g bet e cente th tail tock wh h h l l the tail n r tap red ter i l mped firml in pla e Long w kp eces may b pp ted in th m ddle by eith r a te dy r t mech n lly dri e f ll w r e t whi h m s w th th cutti g tool

Th ngle po t tool held in a tool p t r bl k whi h upp ted n a cr lide and car iag Th t l may b m ed r d ally o l ng t din lly in relat n t the w rkpi e

Angula ut ar p bl and l ng tudinal ta p s m y be t by off ett ng th tail tock o b dj tm t of a tap r atta hm t n th r ar of the lathe whi h a tu t the c l d

Turret lathe Th t l t ck of the ng lath b pla ed w th m lt ded d x ng tool h ld r t rret de gned t h ld ever l tool th m l b m g a t rr t l th Th s ngle to l p t a d mp nd s ally repla ed by a fou p t de i g tool p t P w cut m y b t ken f m both of th t ol m ti g th r n d du lly or imultan ly Tu ret lath a mad rti l m d l w ll h z ntal

H zontal t r et l th e cl ed a th b r r h ck g m hi r f r g t th m n



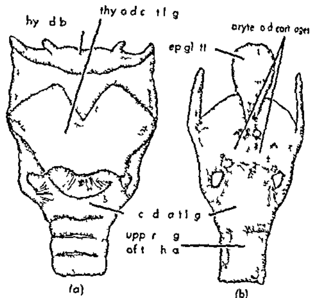
(b)

Larvacea (a) A larvacean O kopleu a d o ca in t house 1 body of animal 2 ta l 3 wate ntake f lter 4 food concentrat g apparatus 5 gelatinou material of house 6 water outlet 7 emergency e t (b) body and anter o tail eg on of O kopl ra d o a 8 Oral aperture 9 pharynx 10 endostyl 11 buccal gland 12 g ll sl t 13 esophagus 14 lobes of stomach 15 a us 16 dorsal ga gl on 17 dorsal ne e cord 18 caudal ganglion 19 go ads 20 o koplast epithel um which sec etes the hous 21 ta l 22 otocho d

posed of polysaccharides bearing amino groups but contains no cellulose In some sp cies this tunic is highly complex and encases the whole body in a house equipped with chambers and trainer which enables the inf abitant to filter and concen trate the finest of plankton from the sea About 60 species are known *Oikopleura* and *Fritillaria* are the largest genera *See* TUNICATA [D P A]

Larynx

In man the voice box The signet shap d cricoid cartilage forms the base which rests on the trachea The paired thyroid cartilages which form the prom inent Adam s apple in front lie above the cricoid Po teriorly there are paired pivoting cartilage the arytenoids Each is pyramid haped and acts as the movable posterior attachment for the vocal cord and the laryngeal mu cles that regulat th e cord Two other mall paired cartilage the cunei form and the corniculate also lie behind the thy roids The lid of the box is the epiglotti a l af shaped cartilage with its stem in erted into the thyroid notch *See* CARTILAGE



Human laryngeal cartilages and l gaments (a) F o t view (b) Back v ew (After Sappey from J Sym ngto ed Qua s Elements of Anatomy vol 2 pt 2 Lo g mans G een 1914)

The larynx is a derivative of the primitive gill bar system of vertebrate Its original function is to act as a protective phincter at the air pa sage a func tion still retained in lower animal Only in higher vertebrates has phonation been acquired it i al most limited to mammals since in birds the sound is produced lower in the airway *See* SPEECH *See also* LARYNX DISORDERS THYROID GLAND [F E ST]

Larynx disorders

Diseases of the larynx manifest them elves b hoarseness and by stridor a form of noisy breath ing caused by localized narrowing in the larynx or trachea

Laryngitis is an inflammation of the mucou membrane of the larynx always as ociated with hoarsene s It frequently occurs with commor colds and as a complication of other inflammatory diseases of the upper respiratory sy tem In diph theria th formation of a membrane of fibrin leukocytes destroyed tissue and l acteria can cau e severe respiratory diffi ulties which might demand tracheotomy The development of chronic laryngitis is fa ored by a chr ni irritation uch a that cau ed by smoking

Hoar ene s is also a manife tati n of paraly i of the recurrent laryngeal nerve of the vagu (*see* NERVOUS SYSTEM) whicl i ea ily lamaged upon surgical rem val of a g it r

Benign tumors of the larynx occur in th e yo inger age group A tumorlike formati n of the ocal cord kn wn as ing r n de often ac int f r th e hoar ene of pe ople who ab u e the vo c Cancer of the larynx i n t unc mmon in man I t is frequently of a sl wly growing typ and th out l k is often good The highe t inci lence i in mal over 60 [F W F]

atent image

a ible im ge produ ed by phy ical or ch m al ffect of l ght n the indi idual cry tal (u a ly sil e h l d) of ph t gr phic em l i n Th i e can be re dered i ble by th pr es known de l pm nt Fo deta ls f latent imag f rm n a d devel pm t se PHOTOGRAPHY PHO-LYSIS (PHOTOCHEMISTRY) [K W P]

aterite

i ame gi e by F Buch nan (1807) t th ir h th r g p od t of b alt n uth rn In

The t rm i n w ed in e mpo ti l ose f atheri g p od ct c mpo ed pri cip lly th des a d hyd ou ox des f ir l m num a m a d m ng ese I h r f rigin u terit l rgel hemat t Fe O nd goeth t FeO d may be an re of ir and n kel Cuba, New Caledo a) Al min u l te te i com osed of gibbs t a d boehm t a d i th pr ci l e of lumi um (se BAUXITE) Cl y m ne l th k l n g p a e typ cally sociated with d r g net cally r lated t later t Lat it g f om soft, arthy po mat ial to hard nse ock Co cret ary f rm of ary g ze d h pe e mm nly a e d eloped Th col r d nd on th co te t of ir n des a d r ng om wh t t d k red b w mm nly a ted. S CLAY MINERALS KAOLI ITE W ATHER G PROCES ES

Origin Late it i f rm d by we thering nder d t that lead t the rem al f l a k l s nd alk l e rth The res lt g n t s f r d al m n m ides h r l d f tenti te l te t zat f m temper te-el mate ther g wh h th e d prod t i la g l clay in al (h d lumi m l cat) Early k s f m i mp ate reg o d ed f t i zat n s pr fou d l h g (d l t) n a g beyo d d n ry ka li zat n St d es in p l regi s h wev sh w that we theri g of k l e l ates may y ld g bb t d r tly w th ut p i g th ough i rmed te l y tag In est gat ma y p rt f the w ld tres ta n g t e f t A t op l t bt pi l lum te w h h gh temp t d b nd i a n ll ase f t le t w th per od l ma k l ry t f nd ment l R l f uffi t t en re ood d a g i eq t l t t l e rm bl nd d t d by h et w h l k f y h l Al m u l terit f rm bov the t tabl nd ma g ad to l y d pth It m y h r d l d pos t i dja nt lley u ally k l

Pa ent materials Th pa e t m t al nt l gr tly fl en es th mpos t n f l t rit h h m y be dev l ped f m ety f ig eo n tam rphic a d ed m ntary ock l n i h ock (p d t t) y ld n l m nou rock t) p od l wh e des t lt g term d t p od ts Comm ly tex tural and tructural feat ires f th par nt material are preserved an l th m r rest t t in full m n er l r m in

Mature l terit c soil la k fertility f r m t y t m of gricultur S an r park like gr land ar ty al n lat rite Clay n t l terit f f nd bene th r inf e t and j ingl v g tati n S VEGETATION ZO E [c]

B bl g aphy Se BAUXITE

Lathe

A ma h n f th r m al f met l fr m a w rk piec l y gripp ng it ecur ly in a h ld ng devi e and r tat g it und pow r gain t a itall cutting tool Th tool may be m ved rad ally r l g t l lly i respect to th turn ng f th w rkpiec eith r m nually r l y att hed power F m h a n pl es n l r l ted c n ntr l aped w rkpieces a w ll a tru yl nd r ca be turn d n a lath Ma h ni g operati h f cing boring a d th r ad ng whi h ar va ati f th t r g p ices a also be per f rmed n a l th

Tur ing eq pm nt may be cl ed being e th f th h ri ont l r ti al type r ferr ng t th t rn g a f th w rkp in th ma h n Th ba ic engi l th i pr m ily a manu lly perated ma hi Filli g th gap between th n g n l the and f lly t mati turn g eq ipm nt i th turr t lath Fa t t d best s it d t h gh q nt ty pr du t n i the a t m t sc ew ma hin

Engine lathe The er t le eng ne lathe *range* i ze d des gn f m mall bench and *peed* lat f es t l g floo type The w kp ec may be h ld betwe n tape ed ter and r tated w th th power pindl by m f a clampi g devi r it may l h ld a h ck r even f ed t a r t i g plat Wh n th w rk i w ing betwee nte th ta l tock wh h *hold the* tat ary t pered nt r lamped f rmly n pla Lo g w kp e s m y be pported n th m ddl l y e the a t ady rest r mecha ally d i en f ll w rest wh h m w th th cutti g tool

The gl po t tool i *held in* a tool po t or block wh ch i s pport d ro l de and c r *r ag The tool may be* m ed ad ally o l ng tu d n lly r elat t the wo kp

A gula ut are po bl a d l git d al ta p a m y be c t by *ff ett g the ta l tock* o l y dj tm t f a t per tt hment n the r ar of th l th wh h act ates th os l de

Turret lathe The ta l tock f th eng n lath n be r pl *ced w th a* m lt ded i d ing tool h ld r rr t des gned *to h ld* es al tool the m h be mi g t rr t l the The ngl tool post d mpo d *u* lly repl c d by a f ur pos t nd g tool post P w ut m y be tak f m *b th* f thes tool m u t ng th r in d d ally m lta eo ly Turr t l the are m d rt al mod l w ll h izo tal.

H zontal t et lath a el d a th Far h k g *m h nes* f rri g to th m nner



Fig 1 Saddl type tur et lathe (Jo es and Lamson Mach Co)

in which the workpiece i held The headstock of the l ar machine i con tructed so that bar stock may be slid throu h it and the collet on line with the turning axis of the lathe The collet closes holding the piece firmly Chucking type machines grasp a unit size workpiece in a chuck or jawed de vice Chucking devices permit work of relatively large diameters to be machined

Horizontal machine may be further classed as being either of the ram or saddle type a designa tion referring to the manner in which the turret is *mounted on the machine On the ram machine* the turret i mounted on a ram or slide which rides on a saddle When the turret i indexed for successive *operation the saddle acts as a guide for the ram* in its trokes to and from the work On the saddle type machine de igned without a ram the turret mount directly on the saddle which lides on the bedways of the lathe (Fig 1) Ram type lathes with their short turret travel are generally of lighter construction than the saddle type Exce ive overhang of the ram redu es tool rigidity Fast in operation they perform be t on mall diameter work and light chucking job The rigid construc tion and the longer troke of the addle type lathe enable it to handle l oth longer and hea ier bar and chuck work than the ram type machine

The *vertical turret lathe imilar in principle to* the horiz ntal macl ine i capal le of handling hea ier and l ulkier workpieces The vertical ma *cl ine i* con tructed with a rotary horiz ntal work tal le who e diameter normally de ignate the ca pacity of the machine Machi e table range from 30-74 in in diameter A cro rail m unted al o e the tal le carrie a turret which indexe in a verti cal plane with to ls that may l e fed either acro or downward (Fig 2) The cro rail may al o carry a ertical swiveling *ram with a n nindexing* tool holder which feed in a manner imilar to the turret Below the cro rail a side head with an in dexing tool holder *is* ometimes pro ided Th i t l may be fed in h rizontally or m ved ertically

Tools may be operated simultaneou ly either man ually or by power

Automatic screw machines When a high pro duction rate of relatively small turned parts is re quired automatic screw machines are u ed The screw machine was originally developed from the lathe for the purpose of more economical manu facture of screws and bolts The name ha per sisted even though numerous partially or com pletely finished products are produced on them. Generally these machines are clas ified as ingle spindle or multiple spindle automatic The u ual machine is of the horizontal type

The single spindle machine is con tructed to feed bar stock through the hollow machine pindle and collet similar to a turret lathe When the bar *meets a stop the collet closes on the piece* The manner in which the cutting tools are held may vary Usually a small five or ix po ition turret or drum indexes and feeds tools longitudinally again t the end of the rotating workpiece Turret to ls may include drills reamers hollow mill and counter boring tools at times a ingle-threading d e mounted on line with the pindle is u ed

Usually two independent cam actuated cro slides front and rear are provided to hold form ing grooving or cut off tool Turret indexing actuation of the collet feeding of stock and pin dle clutch operations are automatic Machining operations commonly performed include *facing* drilling reaming forming and knurling Special attachments permit such operations as milling in dex drilling or thread cha ing to be perf rmed

Multiple spindle automatics employ se eral ma chine pindles arranged in a circular pattern Each *spindle is e uipped to hold stock in* a manner imi lar to a ingle spindle machine In ome in tance automatically operating chucks capable of hold ng irregularly haped workpieces replace the collet type chucks Standard machines may have as many as eight rotating spindles These in turn index in a

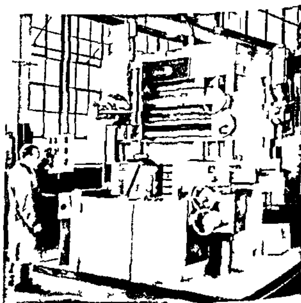


Fig 2 Ve t l t et l the (B ll d Compa y)

arm about a n nr t ting turret wh h l ld a et of utt g tool A a l pindl i dex d pr gre ar d the a ti r iece i e m hi g operat ns a e pe f rmed l th t rr t ools. S multa ec ly tool l c ted m u o ti a pe f rm g thei espe t e pera i o th a w kpeces C lides n u ted at r ght angles t th pindl arry the rm n groo g e t-off tool

Th t m f th l g t it pl t tl ll wan e f r u h pr g amm g a ti n a i de i g nd tool tr e ng et th time req i e l t pr d i e o fin hed pec By d v d ng l ng e t r tw m e perat ns the ycl ng tim may l re duced M h i g perat perf rm d n th ma hi es e g erall th me a th e d n n ingl p dle a t mat

A t l m lt ple- p ndl m h es f th m aut mati h k g t pe e n tr ted w th a m v a 16 p dl A h z tal r ilar t lle h lding the r t t g chu k i de e t nd the ert l pndles w th a d ff r nt p at n l eng p f rmed t h t t n Th ma h e n tr i ted t h dl m h large w kp eces tha h r tal a to ti m y mod l th peed feed and di ect f r tat f r ea h p dl ml ati m y b a ed f m p t n t the t Th p rm t el t n l the t feed and p ed f th p t n be p rfo med t h t t n S MACHINING O R TIONS [A T]

Latite

An ph n tic (t hly ry tall) r k f v l g ompo d h R l d plag ocl (ol gocl a s d) a d lk l feld p (a i d e rthocl e) w th s bord nat q nt t f d k e l ed (mafi) m al (b tit mph bol pyr x e) Latt i m te les i t rm di t betw n t hyt d a de t Pl g l e d m n t alk l f ld p a l tite b t bo d te t alk f ld p t a hyte A desit r e l ttl o no alkali f ld pa S TRACHYTE. [C.A.C.A.]

Latitude astronomical

Latit d det rm ed by t n m al b erv t on as d t *ou hed* fr m g g ph c l ti tud wh h th t h w o m p A tr n m l lat tud d t rm ed b *th* defin t on that th g l r alt t d f m th h r n f th elest l pol i d nt l w th th l t tud f th ob rv The lt tud f th p l e t d by l rv g th me d n h t d f a lest l bje t who e d l t known Th d by m u ng th a gl b t n th l e *f* ght a d ho iz nt l u f h h s tabl h d th by th bl h ri l q u d fa r p n l l d d lly i pe pe d ul *z th* d t n (g ty Th d ect f g u l ally h weve th des t b g *all d d R* t f the t l (Lo GITUDE AST O OMICAL) A m p e t u r d r lu ly f m t o m l b rv ti uld be d t t d by a f w h ded f t t m th n m l S e GE DE Y [G.M.C.]

Lattice (mathematics)

Latt the y l l wit p pert es f r l r an l n cl r m l a gr p tl ry treat sm tr (see GROUP THEORY) A a g n r l z t f Bool n al fr l tt ce tl y w fr t a[l ed r l 1900 l y R Ded k l t lg b r e umber tl r B t it r e m t m j r l a l f m tl mat es r l var a pe t f lg bra geom t y l f t n n l a ly a w ll a f t t ery l m n l pr l b l ty (t w l l Bool n alebr l l al l been appl ed) lates f tl s rs 1933 1938 See BOOLEAN ALGEBRA; SET THEORY

Tl most l a cept f l tt c tl ry that f a pa t l l r f a t S f l m nt x y B th me t l n r l i n i lly l n t l $\leq$ ($r \geq$) w tl tl f ll p pert es

(P1) $x \leq x$ for all $x \in S$
(P) If $x \leq y$ l $y \leq x$ tl $x = y$
(P3) If $x \leq y$ l $y \leq$ tl n $x \leq$

If $\leq$ v pa t l r l ng f S, tl n it v rse l l $\geq$ t f ned l y tl t t nt

$$x \geq y \text{ if and only if } \quad \leq \qquad (1)$$

i l a pa t l r l f S Tl ly r r fed f et p r l f ndam t l D l ty l rin pl wl) ful n m i y e n rret n

Suppos f xampl th y n $x \cup y$ f tw l *m* t l y f part all r l r ed t S l f ed by th n f t n

$$\leq x \cup y \qquad y \leq x \cup y \qquad ( )$$
$$n l f \ x \leq \quad l \ y \leq \quad tl \quad x \cup y \leq \quad ( )$$

(It s ly h w tl t th at m t n l $x \cup y$) Th tl d l t p i e pl ggest d f ng th meet n y l y

$$x \geq x \cap y \qquad y \geq x \cap y \qquad (3)$$
$$a d f \ x \geq \quad a l \ y \geq \quad th \ n \ x \cap y \geq \quad (3)$$

n f h tl t tl e t m t n cl n y

A l tt ce l fi l a pa t ally *o l* l s wh l ny t l m nt x an l y h v meet $x \cap y$ d a j n $\cup y$ Thes l ry perat s t fy f r ba d ti es

(L1) $\cap x = x \cup x = x$
(L) $x \quad y = y \cap x \quad a \ l \quad x \cup y = y \cup x$
(L3) $\cap (y \quad) = (\cap y) \cap \quad n l \quad x \cup (y \cup \ ) = (\cup \ ) \cup$
(L4) $\cap (\cup y) = \cup (x \cap y) = x$

Th pe at n l u n ted w th tl rel $\leq$ l y th e d t that $x \leq y$ $x \cap y = x$ a l $x \cup = y$ th l l nt t m t Co ly f L n l l y t m w tl pe t o n l u t fy (L1) t (L4) f all x y tl n tl p ced l t n def $\leq$ a p t l rd r of L w th espe t t h b n *nd u h* th m d fi ed at Tl p pl was d ed l y C. S P i (1880)

Kinds of lattices Th a many diff nt k nds f l tt ce Th th al mbe s f n l tt f $\leq y$ p n t m ng Th s l tt mply d ed i th th t

(P4) Given x and y either $x \leqq y$ or $y \leqq x$ Any such simply ordered set (or chain) is a lattice in which $x \cup y$ is simply the larger of x and y and dually

Again the set J of positive integers forms a lattice if one lets $m \leqq n$ mean m divides n (usually denoted $m|n$) In this case $m \cap n = \gcd(m\ n)$ and $m \cup n = \mathrm{lcm}(m\ n)$ Still a ain one can let Σ consist of all subsets S T of a fixed ensemble I and let $S \leqq T$ mean that every point in S is in T Then Σ i a lattice in which $S \cap T$ is the intersection of S and T *whereas* $S \cup T$ *is their union Actually* Σ *is a* Boolean algebra

In all the preceding lattices the distributive laws hold

(L6) $x \cap (y \cup\ ) = (x \cap y) \cup (x \cap\ )$ and $x \cup (y \cap\ ) = (x \cup y) \cap (x \cup\ )$ for all x y

Such lattices are called distributive lattices Any chain is a distributive lattice so is any Boolean algebra More generally a ring of sets is defined as a family Φ of subsets of a fixed et I which contains with any S and T also their inter ection $S \cap T$ and their union $S \cup T$ Then any ring of sets is a di tributive lattice

It is obvious that each of the two identities of (L6) is dual to the other It is a curious fact that *in a lattice each al o implies the other*

If G is any group then its subgroups form a lattice and its normal subgroups al o form a lattice in both cases under inclusion The normal subgroups satisfy the (self dual) modular law

(L5) If $x \leqq$ then $x \cup (y \cap z) = (x \cup y) \cap$

In general lattices satisfying (L5) are called modular and every distributive lattice is modular

The lattice of all linear subspaces of the n dimensional vector pace V (F) over any field (or division *ring)* F *is also a modular lattice usually called the* $(n-1)$ dimensional projective geometry $P_{-1}(F)$ over F This lattice contains pecial elements 0 (the zero vector) and $I = V$ (F) (the whole space) such that

(P5) $0 \leqq x \leqq I$ for all x

Such pecial elements always exist in any lattice ho e chains all have finite length But they need not exist in general for example they do not in the simply ordered set of real numbers

The lattice $P_{n-1}(F)$ is complemented in the en e that each ub pace x has at least one complement x with the property that

(L7) $x \cap x = 0$ and $x \cup x\ \ I$

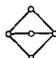
Thus $P_{n-1}(F)$ is a complemented modular lattice Similarly it may be verified that the class of Boolean al ebras is precisely the class of complemented distributive lattices This principle enables one to consider Boolean al ebra as a branch of lattice theory

Lattices L containing few elements can be c nveniently vi ualized by dia rams In these d a ram small circle repre ent elements of L a be ng hi her than b whenever $a > b$ *A segment is* then drawn from a to b whenever $a > b$ but no x exi ts such that $a > x > b$ Any such diagram defines L up to isomorphism $a > b$ if and only if one can travel from a to b along a descending broken line Fi ures 1 5 are typical such diagrams

Such graphs often give u eful information very simply For example let a finite lattice be called emi modular if any tw o elements a and b immediatel above (covering) a given element c are al o immedi ately under (covered by) another element $d = a \cup b$ This condition can easily be tested by in pection Dedekind showed that a finite lattice L was modular *if and only if it and its dual were both emimodular* For L to be distributive the extra condition of containing no sub raph such as that of Fi 2 is nece ary and sufficient



Fig 1 The ord al number 4



F g 2 The project e l ne o er the feld J_2 of i tegers mod 2



F g 3 The s mpl st onmodular latt ce

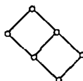
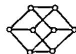


Fig 4 The l tt ce of d sors of 12 u der d s b l ty



F g 5 The Bo l a algeb a of order 8

Applications to algebra and geometry Lattices like groups and rings can be define l as abstract alge bras that is as systems of elements combined by uni versally defined operations These operations may be unary b nary or ternary In any such al stract alg bra A the subalgebras form one (complete) lattice and the cong uence relations form another

Th u gh not many results are val d for al tract algebras in general it is known that any such algebra can be dec mposed into subdirectly irreducible al gebras Using this general theorem of uni ersal algebra it can be sh wn that any distributive lattice i isomorphic with a ring of sets

In group ring a l many other algebras all con gruenc relation are permutable it follows that the congruence relati ns form a modular lattice Th

f t, comb ed ith the ext nce of e-eleme t haageb a permit th dev l pm t f an e t ive act e th ory tl t incl les l f t t at orem d ppr priat f t nes co l t n ly l tt ces them l es t fy a que f c zat on theo m but f r tl er re n

It is important t te that th latt ce p od t I m l ed in the t t m t f th pr ced g pa f ct izat n th em one f tl t t c e tions f ge e l thm t c f pa t ll rd red t h h e t n the us al card n l an l l n l thm t as a pec l ca Tl th m st g n r l t Bool al b a j t wle t th el l mbe t d a fi te l l n imbe

l th ca f gr ps st d es f th l tt ce f all hgro ps ha al bee m de b t l a n t y t led th d ery of fru tf l l tt ce tl eor t c m thod re ge r ll t m h of a pos t tur t y t o n abo t n mod l l tt ces n if tl y ar emimod lar (as the case of th latt ce f ll part f set I) A e t res lt D l rth heorem, h h tates th t ry fi t l ttice m rph th a s l l tt ce of fi ite sem mod l att ce m l rly P M Whitman l a h tl t ry latt ce is m rph c ith a bl tt f th ttice f all part t f s m (fi t) la

It as m nt ed bo e that th (-1) l m l jecti eom try P (F) o a l y g F al mpl m ted mod l latt ce Th most nterest g ppl t s f latt c th ry t ge metry m te f th bs ry t F ta c l t P be any bst ct p j ct g m try d f e l by in d ce rel t Th P t l a c mpl me ted mod lar l tt ce Co rs l any fi t-d m n o l mpl m ted mod l r l tt prod t f p jec ti m t es d a Bo l n alg b

Th p d n bst a t c mb t ial appr ch t p ject geom tr es led t th t u t 1936 by J n N m n of h s cont n u-d m n l p ject g m tries (called c nt g me tries) O F k 1916 de l ped par ll l the ry f p ject g m t es f d c tely fi t d me n B analogy affi geom tries a l be rarded as latt es b t th pp h h f led t less mpl and les t k es lts

Relat on to set theory and logic I t the ry n is f eq tly c ned w th s pe al f m l es f sets h as cl ed ets open s ts m bl t d Bo l ts Som f thes f m l f m Bool an al b as B t th cl sed t (d d lly th pe ts) (t p l cal pace X lly f m l t u mpl m ted d t b tı e l tt $L(X)$ I $L(X)$ th mpl m ted l m nts (wh h c rly f rm Bo le n lg b) th e wh h d t X

Both th theo y f fi te t d th th y f fi te d trib t l tt es e f ly t t l Each s h lattice L ha qu r p tat as th card l po L 2 f th t el m t Bo l al b th a g l fi t part ally o d d t P as e po t M y fi t-d m al d t b t l tt ce fi t

If L fi te-d m al l tt d t b t n t, th n d fi l t pol m L

which may mas n t be eq al nt M t f tl es ar gested l a e n ler t n f tl pe l e tl t I t th rat l n ber yst m A l t g Dedek l c t a f t) wn 193 l y H M M N ll ne can xt n l any l tt (r part lly l ed s t) t c mpl t l tt in wh l any l t f f el m nt x h a l t upper bou l (j n) $\vee x$ l gr test l bo l $\wedge x$ In su l a c m pl t l tt e on ca l f n l m t p l j n l l m inf l l f ny eq ce x_1 x x_n of l m nt One c l fin a c ny g n t pol gy in I l y l tt g $x \to x$ m a tl at l m j $\{x\} = l$ m inf l $l = x$ Alt ti ly c n l fn n nterv l t pol gy ly tak ng cl ed int r al $[\ b]$ cl c t of ll $x \in I$ w tl $a \leq x \leq b$ a l ha f cl ed et

The co c pt of co rg n in latt ces a d tl r p ces ca be t led l y n l ring l r cted set f in l ces α tl e cept it ll be ng l ttic theoreti T les r be c n g ce n t pol g cal paces n t sat fy g t l l ty x m s cl l r cted sets r es c t l

U g tl e ncepts f l tt mpl t es an l l tt ce t pol gy e a gi nte esting ha a t r zat f ar s latt es a ocated th t pol gi l spaces Th tl s l ne f tl e l tt f e gular pen t l y S Ulam l C B kl ff It was l n f r th (l tr l ut e) lattic f t n fu ct by Irv Kapl ky F ally t a l f r l ed (l pen) t l y J C C McKinsey an l Alf ed Tarsk ll nc 193

A nt est a l g bet ee t th ry n l l t pr ded l y tl j v l n between th al bra f pe ts n l ll e n l g whcl r nt ly f m a c d at n of f rmal l g c Al t a tly l th d t w th r lat ly pe l c mpl m ted d t l t e l tt ce

A tle type f l c d rectly ggested l q a t m th ry was d el ped n 193(l y C B kl ff l Ne m n l tl l m p pe t f rm an th c mpl me ted mod l r l tt ce Th A t t l an l c f l l me han s appe rs tl pec al d st b t e (he Bo l) ca f permutat l b at The f rmal p pe t es of the pr bab l ty $p[x]$ of e t x sh n t be m l r t th e f d me n n p j ct g metry

Latt e theo y l s gi es pe pe t the kinds f f rmal log c l d mod l l g c a d t t mpl cat H s nce the deepest p blem of f rm l logi c cern th f nd t o f t theory thes ppl t n w ll not be d u ed l e

Lattice-ordered groups The first t dy f l t t e-orde ed g o p w made i 189 by Dedek n l n lyz g th p pert es f th r t n l numbe sys t m R Lett $\leq b$ s gn fy th t $m = b$ f r m nt g r m (that th t b t a m lt ple f) the nz r t l umbe f rm latt ce n wh h $n b$ d $u b$ a m th l m and gcd f a d b Al w th pe t t o d ary m lt pl cat n the nze r t ls f m a (mmutat) gr p F lly R

$$a \leq b \quad \text{mpl} \quad \leq bc \qquad (4)$$

t ch cal la gu y gr p t sl t n a l tt a tom ph m A y l ttce L wh h t l

group and which shares this property is called a lattice ordered group or l group

Though many noncommutative l groups exist it is a striking fact that every complete l group is necessarily commutative

Lattice ordered groups arise in function theory as well as *in number* theory If $f \leqq g$ means that $f(x) \leqq g(x)$ *for all* (or almost all) x then most function spaces of real functions form lattices They are also commutative group under addition Moreover

$$f(x) \leqq g(x) \quad \text{implies} \quad f(x) + c(x) \leqq g(x) + c(x) \qquad (4)$$

for any $c(x)$ this is simply (4) in additive notation Hence most (real) function spaces are l groups In addition they are vector spaces in which

$$f \geqq g \quad \text{and} \quad \lambda \geqq 0 \quad \text{imply} \quad \lambda f \geqq \lambda g \qquad (4)$$

The l group with these additional properties are vector lattices Although E H Moore and F Riesz had discussed related ideas earlier the first systematic analysis of vector lattices as such was made in 1937 by L V Kantorovitch

The application of vector lattice concepts to function theory is still not very far advanced Using the intrinsic lattice topologies defined earlier and others related to them one can avoid the necessity of introducing a distance function in many function spaces Thus the notion of metric boundedness is equivalent to order boundedness for functionals on any Banach lattice and metric convergence is equivalent to relative uniform star convergence in a purely lattice theoretic sense

An additive l group which is also a ring and whose multiplication satisfies the partial analog of (4)

$$\text{if} \qquad f \geqq 0 \quad \text{and} \quad g \geqq 0 \quad \text{then} \quad fg \geqq 0 \qquad (5)$$

is called a lattice ordered ring or l ring Such l rings have been studied systematically only since 1955 a typical theorem about them is the following An l ring is a product of simply ordered rings if and only if it satisfies

$$a \cap b = 0 \quad \text{and} \quad c \geqq 0 \quad \text{imply} \quad ca \cap b = ac \cap b = 0 \qquad (6)$$

Applications Already it is clear that the concepts of vector lattice and of l ring are essential in various physical applications This was first apparent in connection with the ergodic theorem as proved in 1931 by G D Birkhoff and John von Neumann for the deterministic processes of classical mechanics A generalization of this theorem to stochastic processes whose natural formulation is based on the concept of a vector lattice was proved in 1939–1941 by Shizuo Kakutani and Kosaku Yosida

A second application is to the theory of Reynolds operators or averaging operators arising in turbulent fluid motions The essential connection with the order relation is simply the obvious principle that any average of nonnegative quantities is nonnegative Using this principle and the theory of l ring one can decompose (subdirectly) any vector averaging operator into scalar components

A third application is to the concept of criticality in nuclear reactor theory Neutron chain reactions involve the birth (through fission) *migration* and death (through absorption) of neutrons The laws governing the evolution of the statistical distribution of neutrons (as functions of position x velocity v and time t) evidently carry nonnegative distributions into nonnegative distributions To deduce the mathematical principle that the neutron distribution must satisfy the asymptotic relation $N(x, v, t) \sim e^{\lambda t} N_0(x, v)$ λ^{-1} being called the reactor period it is a common convenient to reformulate the problem in lattice theoretic language One can then apply results of Oskar Perron G Frobenius and R Jentzsch on positive linear operators to prove the desired result *See* LOGIC RING THEORY [G BI]

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Lattice constant

A parameter defining the unit cell of a crystal lattice that is the length of the edges of the cell and the angle between edges If the unit cell is a cube the side of it is the lattice constant and it is usually in this sense that the term is used The lattice constants of simple compounds of the type A X A X_2 having the sodium chloride cesium chloride zinc sulfide or calcium fluoride structure have values between 5 and 10 angstrom The lattice constants of the elements and of a variety of compounds are listed in the reference given in the bibliography *See* CRYSTALLOGRAPHY [W D]

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Lattice vibrations

The atoms in a crystalline solid do not sit motionless at the lattice sites of the crystal but undergo periodic oscillation about the sites which are positions of equilibrium As the crystal is heated the amplitude of the vibration increases If the heating is continued the temperature of the crystal eventually reaches a value at which the vibrations are quite violent and the atoms then break away from their lattice sites The solid can no longer retain its crystalline form and melts On the other hand if the crystal is cooled to the absolute zero of temperature the amplitude of the vibration does not subside entirely A residual vibration of the atoms which is quantum mechanical in origin remains It is called the zero point vibration

Lattice vibrations are involved in many of the temperature dependent phenomena of a solid For example the electrical resistance of a metal at room temperature arises primarily from the scattering of the conduction electrons by the vibrating [illegible]

The h gh r the t mperature a d h nce the more lent the ibratio f th at m the m re the electr s a e c tte ed and the higher the electri c l res tance be me A ferr m g et ld l e-comes p ramagn t at temp at r abo e the C ri t mperat r bec u e the lattice vil rati n r th ffic entl energ t c t r m tl t atom mag et c f e The Bardeen Coop r Schrieff r the ry f percond ct ity pe t l t that btle int acti n between l tt ce ibrati ns d co d ct electro a e mainly re p il le f th ph n m n n S SUPERCONDUCTIVITY

Latt es l t n ond i t h t thro gh a c y t l so a k o ledge f th ibrati mech ni m i e sent l t an nder t d g f the heat co du tivity of cry tall e sol d

The theory f l tt b ati began an eff rt t e pla p ifi heat Theory h w that th l l t tm nt f ib ti n f t m n sol d le d t th D long P tit l w f pec fic he t a law wh h t ot beyed at all t mpera t e (S ECIFIC HEAT OF OLIDS) T acc i t f th f l re Albert E te f rm l ted a theory h h sumes th t ch t m b tes w th th same f q n d th t the rgy f vil ti q a t zed Th n foll d the mpro eme t n the theory m d by P Debye a d by M B rn d T n Karm n l both f th se theor e th ngl Ein t i f qu n y pl ced by n ac u t l pe trum Th th y f B n d n Karm r q r that th pect m b bta ed fr m th t dy f th nb ti n f s tem f po t p ticles d trif ted in th m m n the t m a y t l l tt e Th ri s m del repr sent g a g en l d d ffer l m o a the esse ti lly i the a mpt m d ern ng th at f th f es betw e the con t t ent p t l lt u ally i the n l th B n Ka man th ry and t xte n th t n pe k f l tt b ati n

One-dimensional lattice Som f th m in on ept f the B rn n K m th ry ll s-t ted by th br t f a s mpl one d m n l l tt e F e l sh w uch l tt e m po d of q d t t id nt al p rt l f ma M Th q l b m pa at on f ghb ng pa t les Th y loc t d l x th lo-cat n l th th p rt l be g $- a$ A m ly betw e t hb d that the e f be Hook law l F l th f c a e rep esent d h m t ll by pri g w th H ke co t t

Let d t th d pl m nt l g the x f th th p rt l f om t q l b um p t t na Th f ex t d n th th p t l d pe d p n th d t n wh ch th tw p i g

Fig 1 O -d m l l tt f q d t i d t l part l

nected to it re stret h l The exten on are $(u - u \quad)$ f r th left hand pring and $(u_{\ 1} - u)$ f r the r gl t hand pring Th u tl quati n f m ti n f th nth parti l i

$$M(d\ u\ /dt\ ) = -\alpha(u - u \quad) - \alpha(u - u_{\ 1}) \quad (1)$$

Let the length f the lattice l $l = Na$ tl at there are $(N + 1)$ particles in all The number N i taken to be large c mparal l with A gadr n mber that wheth r the d j rti les are fre t m e o e f ed in p ti n i of no practi al importan e he e T e Eq (1) wr t t ntati ly the eq ati n f a w e of fr q cy and ampl tude A namely

$$u = A \exp[2\ i(\ t - k\ )]$$

where $k = 1/\lambda$ the re iproc l of the wa l ngth H we er th lattice di ret and tl was l s n real e i ten e between tl e at m Thi lead on t put $x = na$ The tr l s l t n i n w

$$u = A \quad xp\ [2\ i(\ t - kna)] \quad (\ )$$

S b titut n h w that thi pres ati fes Eq (1) pro ded that

$$= \quad n - k \quad (3)$$

wh e $= \sqrt{\alpha/- M}$ It id t tl at i tl highest p rm ll frequ If tl en l pa ti l are imed t be imm al l th n tanding wa e h t re ppropriat and ar an l g u t th e f the ti t ing w th f ed end Th e tri t n n the wa el gth ar $j\lambda/ = l$ wl re j is an int g ndic ting the number f loop in the part lar ta d g wa e Thu Eq (3) l e-comes

$$= \quad in\ (-j/2N) \quad (4)$$

the a ge f j being $1 < j < N$ Each kind of il a t is called mod f br t nd tl r i s m d f ibr t f a l j Th th e r N mod s The t t l mbe f modes al qual t the mbe of p rt cl l eca N d $N + 1$ e b t eq i l

Th ph e l ty U a d th g p locity U an b le lat d f m Eq (2) i ng the d fi i t $U = /k$ a d $U = d\ /dk$ Tl r lt r

$$U = U_\infty \frac{\quad n\ \pi ak}{\pi\ k} \quad (5)$$

$$\text{d} \qquad U = U_\infty \cos \pi ak \quad (6)$$

H e U s th l ty of nd t l ng w e-l gth and h th al e $-a$ o. By l g w le gth is m a t w le gths whi h a e g t m p dt th eq l br m d ia ea

An imp rt t ch a t r t rev aled by th tre tm nt the d p d of the loc ty on w el gth S h d p nd n alled d per i n It b m e gly imp rt t s the wav le gth pp o h th al $2a$ At th cut ff w l gth $\lambda = 2a$ th gr p el city zero A t nuum th ory h a D bye s g s s mply

$U_p = U_g = U \quad - \pi a \nu_0 =$ constant and the medium is dispersionless

The number of modes $g(\nu)d$ with frequencies between ν and $\nu + d\nu$ can be calculated from Eq (4) by noticing that this number is also given by dj From this the distribution function $g(\nu)$ is

$$g(\nu) = 2N/(\pi\sqrt{\nu_0 - \nu}) \qquad (7)$$

Figure 2 shows a plot of $g(\nu)$ for the lattice as given by Eq (7) and for the Debye continuum theory The latter is simply $g(\nu) = 2N/\pi\nu_0$ with the range $0 < \nu \leqq \pi\nu_0/2$

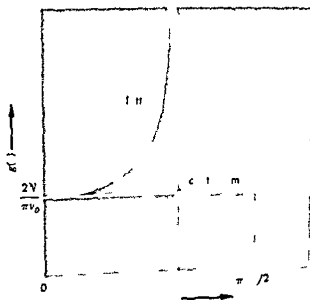
The energy E of the lattice is given by

$$E = \int_0^\infty \frac{g(\nu)h\nu\, d\nu}{e^{(h\nu/kT)} - 1} \qquad (8)$$

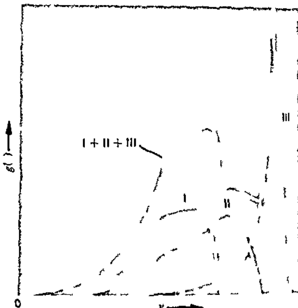
where h is Planck s con tant k is Boltzmann s constant and T is the ab olute temperature

Three dimensional lattices In three dimensional models some attempt is usually made to approximate the conditions in actual crystals At the same time the considerable mathematical complexity of the problem requires that the model be kept as simple as possible A decision ha to be made concerning both the number of neighbors to be included in the calculation and the types of forces acting between the particles before the equations of motion can be formulated

The forces are of several kinds A force which arises when the distance between a pair of neighbors changes is called a central or radial force This is the type of force assumed for the one dimensional lattice discus ed earlier If a change in the angle between the pair of lines joining a given particle to two neighbors (bond lines) gives ri e to a force the force is called an angular force A more general force compounded of radial and angular forces is often referred to as a noncentral force The mo t general combination of noncentral forces compatible with symmetry requirements



Fg 2 The funct on $g(\nu)$ for the one-d men ional lat t ce and the o e-d men o of cont n um



Fg 3 The function $g(\nu)$ obtained by Le ghton for a face centered cub c lattice (After R B Le ghton Re Mod Phys 20 165–174 1948)

about the particles is commonly called a ten or force

The types of forces just named are defined for a pair of particles or a pair of bond line The motions of the other particles or bond lines in the vicinity of the pair do not affect the force between the pair In metal however the conduction electrons give rise to a type of force which cannot b defined in this manner To visualize thi imagine that a group of particle (po itive ions) move toward each other thus increa ing the local den ity The corresponding increase in po itive charge density is immediately compensated by a flow of conduction electrons into this region However th compres ibility of thi as embly of electron called an electron gas is small and the gas re i ts this increa e in its d n ity The electrons would thus screen the ions le s completely the ion would repel one another more trongly and con equently a stiffening would occur in the elastic constants involved To summarize additional f rce ari e to oppo e any change in particle den ity This i clearly a cooperative or collective effect not covered by the type of forces ju t li ted The forces produced by this collecti e effect are sometime called volume for

A common objective of the theory of lattice vibrations is the calculati n f the di tributi n function $g(\nu)$ Analytic method generally cann t be u ed and the calculati n mu t be d n numerically R B Leight n (1948) calculated $g(\ )$ for a model f a face centered cubic lattice with central f rce between neare t neighbor and between next near t neighbor Figure 3 shows hi re ult obtained after much lab r f r a electi n of force con tant approximating copper The availability of high peed digital c mputers ha n w reduced th labor to th extent that cal ulati n of di tributi n functions are becoming increa ingly c mm n

F gure 3 h w three l ran he f the d tril u f t l beled I II a d III In an la ti call 1-otr p sol d bra ches I and II w l l o respond t t a wa e and br nch III t l ng t d l w f r λ ≫ ∠a I n l ti ally anisot pic cry t l ery few wa es ar pu ely tran er e o l ng t d n l even f r λ ≫ 2 Th m tual cry t l the wa es co t tutt g l ranch I d II ar ly p ed mi ntly tra r i hara t r nd th e t bra ch III lv p l m anil l ngn d l Latt es n whi h a l at m has e ctly th me e ir nm t s any th t m re B a latt e a d th e alw ys ha e three bra hes in the d t l ut n fu t n Tl d str b t I nct I n n Br ai lattices h a N Cl nd d m d ha e add t nal h gh fr q ncy b a h lled pt al bra h The I fequ y br n hes, rr p d g to th three bra ches f th Br is l ttices, are alled ti al bran hes.

Expenmental studies The e lt f the calc i l i f g( ) f r a g n model e ften tested b e mp t g the pe fi h at and tl n mp ring th res lt th the m ed pecif h at The c mparison h h ha e bee m d le little d ubt th t the B n on Karm theory c n a cou t sat f ct ily f r tl d crep nc es betwe n th Debye theory of specifi h at nd th exper m t l m u ment P ec age ment between th al btai ed fr m th pec l mod ls nd xperim nt h n t t been a h ed h w A part l r d d t f th p f l at ap pr h s the t ty f th pe fi h t t the d tailed h pe of th d trib ti n f t n f r f e q en bey d th fir t p ak

An th p im t l pp h i the t dy f th sc tt ri f r ys by l tt e b at A t t l ttı e h ld p od harp d ff ctt pat f s c nf rm ng t th g l rity f th latt If a w p e th gl s h a l tt e a peri d c r l od ced the l tt ce d a p l p ts (gh t) may oc n e th r ide f th q n, pal d ff r m imum II th mbi ed ffect f ll po ble w i de ed th es lt b o d diff ed p t e te ed t th d ff et m imum Th theory of th eff t w fir t g 1918 by H Fa n d p m t lly b rved 1938 by J La al Th th ry nd p rim t l method a n w dev l ped t the t nt th t d per n urves f l tti b at n n b d t m ed f m th ob rvat Th r d t m ed f r pec al d ect th ry tal s g m no brom t c x r ys. Th d pe n urves bta d a th mpa ed with th g n by a mod l P m y d ffi ult e e the c ct f d pers rv a t e d C n all th m thod seem t b poo t wh e the p c fic h t m thod be t th t th t m th ds an b used d t g u l t uppl m t the A th d e p m nt l pp o h th tudy f th l t tt g f ld (ery l w) e tr by latt ib at It p bl t u

alm t m n cl r mati l am of ne itr n with n erg e c il r lly les th n tl e ac tured I y therm l att ring n j a ag tl r gh tl l tt Th trary t what happen t x ray f r which th ph t n energ i gr at a t l a ely hanged l y tl ermal sc ttering Th tl eo y of ne tr n scatteri g bec mes s mpl fied if tl scatt ring i also i l r t S NEUTRON DIFFRAC TIO [J n l]

B bl og aphy W H Bragg *Th Cry t ll n St t* 1933 1953 L Brill in *W e Fropag t o i P ri dic Str tu* 1946 S Flugg (l) *Ha dl uch d r Phys k* v l 7 pt l 19 5 F Seitz and D Tur l ll (ed) *S l d St t I hys cs* l 2, 1956

Launching pad complex

The mpo ite f ipporti g fa l ties req ed f r tl e e ti p p r ti n f r l unch and la n h l a g u d l a ed rock t pr p lled l i l Tl es fa l ties ary fr m a imple tru k m unted ra li g an th ca f a m ll t ti al l l pr pell nt mi le t th pe ma t mpl x f eq pm t d ut l t es req ired f r th pp rt f larg l y il pr pell nt m iles i a es a cl n l level pm t pr gram (Fig 1) Tl latt will l d ribed f r t

Launch stand The l i ch tand in l des fa il t es fo m ta m g the m il i th rect po t n wh le l a i perat n a e perf med h a check t of l y t m an l i tr m rt t n lu l l ad ng w ghi g and th r la h t d p para tio f r m il flight (F g 2) Spec l f ilt re ft p d d f p rform g xtended e g firi g th lau ch tand either t t t or e t bli h g d es f r l n h Thes i l l w t co led flame d fl t r f r di e t g th en gine haut d a h l l d wn an l r l a y t m The l tte q i m nt u lly w k ju t n with th weigh ng a d tl t m a g d es

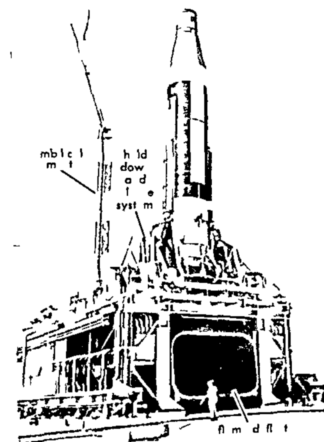
Th w igh g y tem a p t l ly important p t f t d equ pm nt it m y l u ed fo w ghi ng the m il d t m g th am nt f p pell t l ded a g the thru t n t t test a d est bl h ng ept ble thru t pe f rm a c pr r t l ch ng f m le W ghing m ha m ge rally l ad cell tr g ge

An umb l al t w i ft p ided fo upp rt i g th w ght f th cables g l es d f l ng l e wh h q r n t t th m l ipt th t m of la n h

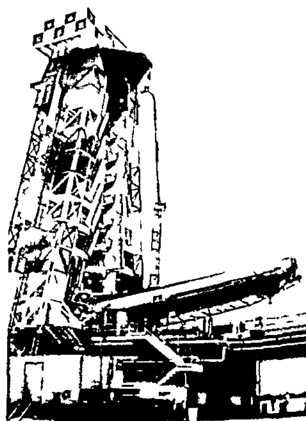
I dd t t thes fi d t ms a rv c t w r g nt y s p o ded f r p m tt g e t th m l wh t d k s n pr g es Tl rv e t t i d gned t surr d th m l p rt all with r t t bl wo k platf rm t t d t l l wh h r p nd t m l c d (F 3) S h des gn p rm t techn s t rv e d t t t al t m of m l bo q p me t wh le th m l st nd r t The ers t w r lly d gn d t f ld b k r ll w f m th m l t k

B the t g ti g b l tv f m l d pe d p k l dg f l n h nd t g t

F g 1 Atlas ICBM fl ght test la nch compl x



F g 2 Launch stand for l qu d fu led ICBM



F g 3 Service tow mi le b i g er ct d



Fig 4. Th IRBM blockho se



Fig 5 Rec d' g f typ c l bl kho se

locat o acc rate geodetic rvey f th la h s te is gu ed F rth m re n opt l lignm t stati n u u lly n l ded t the ite f r th p r pose f est bl h g r f n a es f th m le guid and nt l y tem

Bec u e afety c n iderat n l n t fr t l nd b ers t n atı ı r m t am ra and l ed l oı tel ı t n sy tem are generally mı l ed in the v c n ty of tl stand f r l rving a l rec rd ng e nt dur ng live pe ati n

Tl e laun h ta d an l ervice t wer may incl ide a c mplete water del g y t m l r ntr lling f res Tl ı but e f many mean pr ided t protect ı r n l a d eq ıpm nt

Blockhouse A typical f ed mpl f r l rg el ı le m l d a l l kh ı designed t pr t t men a d ı ıpm nt fr m l la t r f l ring a n r mal la n h r f m accid ntal exı l ı n f tl e l le during te t (Fig 4) The l lockl ı e c n t m te t and tr l n les a d rec rd ng qı p m nt th t the mı le may be l ecked an l fi ed r m t ly and d ta f m test rec rded a t mat c lly (Fig 5)

Tl d g f the l lockh ı will depend ıpon tl l a te ties l tl ehı l t be test d In design ng it pr tecti feat res n take ı t n id rati n th destr ti f r es resulti g f m tl l igl t rder e pl ı n tl v h l p pellant m y l pected t p l e t spec f ed d tan e f m tl blockl ı e W ll thickn es may r nge from a f w l e t er l f et an l v rying tr ti tecl n q es m y be ı ed A tyı ll rge l lockl u des g ed f r th T tan pr gram ı n tru ted l app x mat l 5 ft f rei f rced c n ete c red w th m v f t of l under a t ı ı g l yer f t l m h nd gun te It will with ta d er p es ponding t n pl ı f 50 000 ll f TNT at d ta f 50 ft

Blockh u d ıor h ld be des g ed t w th t nd th am r p es re a the w ll of th

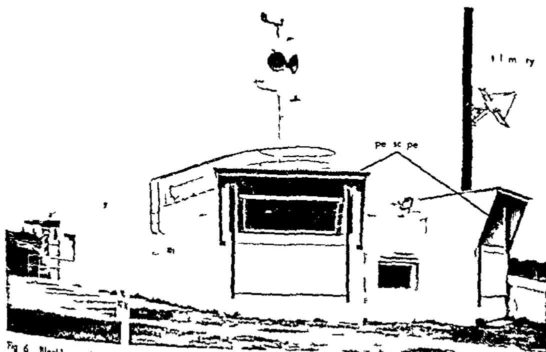
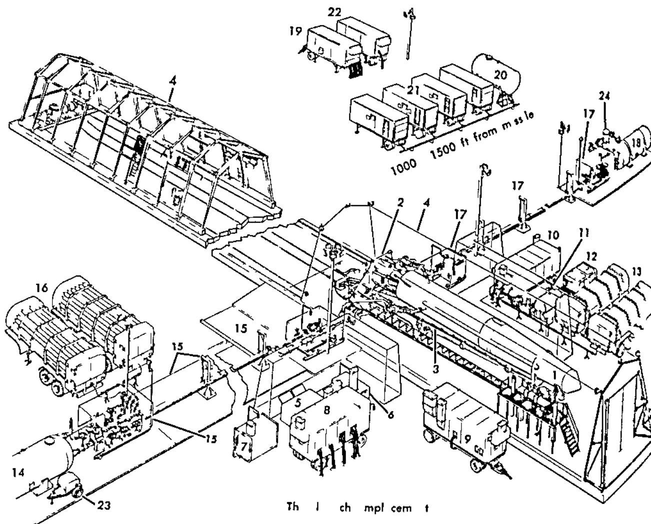


Fig 6 Blockh f m ll l d p p ll t d dy m typ m f



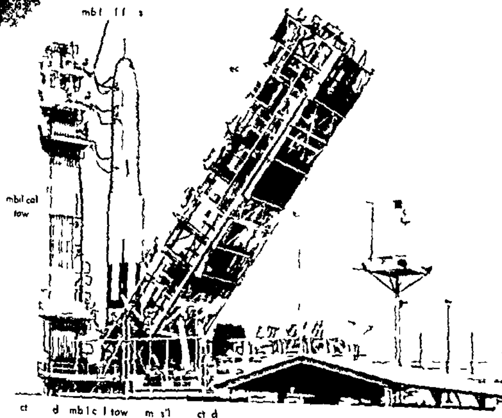
Th l ch mpl cem t

1 Th m l
2 b ll t m ss l e ect g l h g m t
3 b ll t m l m t le
4 p l d p f b t d b ld g
5 hyd l p mp g t
6 t l m t d d t
7 k d m t d pow w t hb d
8 t l m t d m l l h g o tdow g p
9 t l m t d b ll t m l y t m h k t t t
10 t l m t d hyd p m t c yst m c t ll
11 h gh p s g t g t k
12 p w d p t g mp
13 mp d g s yl d s m t l (g s t g)
14 l q d yg st ag t k
15 l q d yg p p l tfit
16 mp d g cyl d s m t l (g s s o yg)
17 f l p p l o tf t
18 f l t g t k
19 t il m t d pow swit hbo d
20 d l f l sto g t k
21 t l mo t d d l g g at s t
22 t l m t d l h g t l g vp
23 t l mo t d m p mp
24 t l mo t d f l flt t

F g 7 La ch g s te for Tho m s le T l mou ted eq pm nt erects checks out f el and f es th mis s le

tructure it elf Baffled underground e cape hatches and tunnels are ometimes u ed o that in e ent of a missile crash near the l lockhouse door a safe exit may be made by the per onnel in ide Air in take for the air conditioning sy tem will l e through such remote e cape tunnels if po il le During a launch all fresh air intakes are clo ed and only re circulated air i u ed Blockh u e for smaller mi ile may safely include peri copes for visual b- ervation (Fig 6)

The l lockhouse is connected to the launch stand l y a cal le al e or l low ground wl ich i u u ally prot cted against destruction l y f re or l la t The cal le may contain hundred of wire pair thro igh which monitoring and control signal pa during ground check out and initiati n f th la inch pha e Terminal room are pr ided at tl l lo kh u and la incl stand f r acce t all tl c nd i t r pair The e ro ms may al c ntain c n trol an l rec rding e juip m nt a well a c mpon nt



8 Td ct d mb l c l tow m s'l ct d

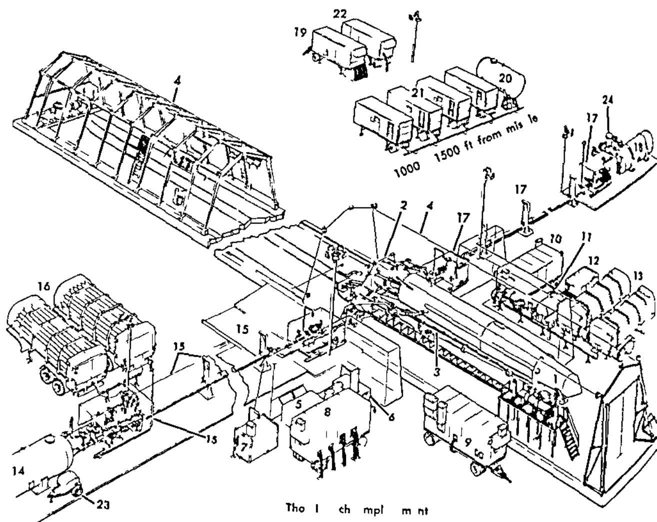
the tim ng l nch q e c *ground support* l mm nications equ pme t

Ground support equipment *The n tu e and* t of gr d s pp rt equ ı me t (GSE) *var es* tl f m m l t m ssıl B dly GSE all m d eq pme t es ry t t a port erv ce l c nt l a d la n h the mı le ı o d ng that equipm nt furn l ed s part of th h le tem (Fig 7) I th gr p ng a h ndling pm t tr port t a l r th rv c tow l ect ng m ha m a *mbly* and l h te t pment a d s les w gh g m ha m bil c l yst m tr l nd n t ume t t n d the t l qu pment ta l ed t the le and req ed f r t p epa t on nd p n F ed t m th f c l t e gr p re lly ex l d d f om th GSE *ategory* Test nd ont ol f ct n lude mean for re d ng th rw d play g r tı l mea l la mea f r t t g and d t at d w bo d th m l C t al p met s h a p ltages a d l y cl r m t served to p t ev l t n f m f tatu rta f t m y be ut mat c lly eq d mp ed d ev luat d nd th m y b e ed em l) l m l per t n bec f the ty l th e c e f *huma* jud m t

Fueling facilities F ch launch c mpl x f r *l quid fueled* m les h fuel and xid zer *stor ge* a d l ad ng sy t m O dı er f the c y g n c (l w t mp rat e) type ntr bute *g eatly to th* mpl xity of the lau chı g fa ıl ty St r g m t *be pr ided* lo e en ugh t th point of u o th t ap r zat f the l q ı d d e n t take pl e *at too r p d* rat ın the tr *ler l ne* Howev th st age p nt m t b f r gh l k f m th launch p int so that the tak *-off bl* t w ll n t en d g the t ag ta k

E t m cl a l e s e e ry n ha dling liq d o yg n the m t *comm* n of o ıd er Ta ks nd l mu t b th *ughly clean* b au und r p pe o d t n *l yd carbon* may omb n with an x dı t t e fir r *pl s n Filt r* mployed ı th y tem to trap pa t cle wh ch m y ha b e d *tally* ntroduced L q ıd y gen ha *a no mal* tempe atur of −297 F and t m ımı l e th cry gen tanks a e d ble j k ted with a u m th nnula p ce The ent e y t m ı u u lly *mad* of tainless te l for e of *leanl* nd t gth at l w tempe a tu

O *d zers such* a f m ng n t ıc ıd pre t d d t o al h dl ng p *oblem* b c e of their t xı a d o natur



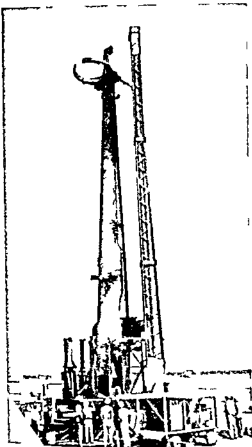
Tho l ch mpl m nt

1 Th m l
2 b ll tc m l t g l h g m t
3 b ll tc m l s m f l
4 pa el d p f b t d b ld g
5 hyd a l c pump g n t
6 t a l m ted a a d t
7 k d mo t d pow w t hboa d
8 t a l m t d m s l l h ng tdow g p
9 t l m t d b ll t m l sy t m h k t t t o
10 t a l m nt d hyd p m t c sy t ms t ll
11 h gh p g st g t k
12 pow d i c p oc t g mp
13 mp ed g yl d em l l (g o s t ge)
14 l q d yg to ag t k
15 l q d yg p p l tf t
16 mp s d g cyl d s m t l (g s yg)
17 f l p p l tf t
18 f l t g t k
19 t l m t d pow w t hbo d
20 d l f l to g t k
21 t l m t d d l g g t s t
22 t l m t d l h g t l g o p
23 t l m ted m p mp
24 t l m t d f t f lt t

F g 7 Lau ch ng s te for Tho miss l Traile mo t d equ pme t erect checks out fuels and f es the missil

structure it elf Baffled underground e cape l atche and tunnels are ometimes u ed so that in event of a mis ile crash near the l lockhou e door a safe exit may l e made l y the personnel in ide Air in take for the air conditioning y tem will l e through such remote e cape tunnels if po il le During a launch all fre h air intakes are cl ed and only re-circulated air i u ed Blockh u es for maller mi iles may afely include peri cope for vi ual ob-servation (Fig 6)

The l lockl ou e is connected to th launch stand l y a cal le al ove or l low ground whi h i u u ally prote ted again t de tructi n l y fire or l la t The al le may contain hundr d of wire pair thr ugh whicl m nit ring and c ntrol ignal pa l iring gr und he k out and initiati n of the la in h pha Terminal room are pr id l at the l lockl u e and l in l tan l f r ac t all th n lu t r pair The room may al o c ntain e tr l a l r ord ng equipm nt a w ll a compon nt



Fg 10 Typ l IRBM t p rt -e ct mb l l st d l h f p t l

f o ectı f mb l l F mpl f th e h l t t e p mit c e t m ght be m de ly t th b f th m le, d mbil al t ld b q ed

Pad for solid propellant rockets I th f ert lly l hed l ge l d p p ll t k t th l h mpl x m l t th t desc b d f the lıq d e pt that th tem q e t the h dlıng f l qu d m tt d W gh g f the mı le m ght b m p d t ly c mpl h d ın a mbly a, d t t t t w ld n t m lly b m de t l h g te Th h t t d b rn t m f l d es p t l ft ff m k th dry t d tt t e I th s typ f t d th fl m d fl t m y t l m t l with h gh h t p tv p t l m m m y gn th p blem lt g th S h m th d l m t th d f gr t q tt f l g t d th l bo t pl mb g y tem q d f w t p d

A sp l p bl m th t w th l d p p l l ts th t f d l w th l g qu t ty f h ghly fl mm bl d lly pl m t l B sol d p p ll t t th m l t th f t ry th t l h t d h k t m t l nd ted w th th m l h za d d F th m ı b y t m ft h k d t p t ly f m th m l p p d

the tıre l icle a mbled t the l unch mplex I thı c e th mpl x ntain an ı lated s- embly area w th elaborate af ty and f e-preve t pr ı o

For mall e t ally l unched r cket the laun l ıng facılıty ı m h ımpler Tl ll kh m y l e r pla ed l y a c n r t wall a d the laun her and fl m defle t red ed t a te l r ng n crete p d

In the a e of n n rt ally laun hed mı l a ze o-le gth r ra l type launcher ı oft n u ed (Fig 9) The l l g c mplex might al c ntain a comm d tatı n f r pr ıd ng ı tructı n t the eh cle f r l h r rec ery

Operational systems The launch c mplex ın the h d f troop d es n t ry g fi ntly ı p ın ciple fr m th t r q ed f r test l ı t man ch g m y l made ın d feren t p ratı nal c ncept The te t f t h nges fr m a p ım ry part f the pr ced e t the m mum required t a h eve h gl p bal l ty of ucce f l la h (Fig 10)

F mall mı le th l lockh u e ı red ed to a mode t tru ture ften a dl g revetm nt ff es Wh e m l l tv mp rtant a d po l le e m de f m lt ple p rp l les w th the ab l ty t tran p rt erect a d l u ch ngle mıs- ıle

F l g m ıle requ r ng hea y l gı tı up p rt th e ı n trı ted hard la nch c mple Thı ın l ma p te tı gaı t near-direct hits by e my m ıles In th typ f peratı n ne may fi d th entır l ı nch c mpl u der g u d w th l y tem w ll d per ed Ma y ı ch m l mple es ca b ntr lled f m a ce tral c mm d p nt [J T]

Lava

M lt rock m t l that che the earth s face thr gh olca e t a d fi res al the gneo r k f rmed by c ol d t f h m l t n m ter l R l t ly rap d ool g at th th f may t f m fl d la ı t d te t ed l nıc rock c mpo ed f tı ery t l gla s b th M lt r k m t rı l b l w th earth f h w ı lly kn wn a m gma d up l g gı e t e-gra ed ıgneo r k h g t gabb

M gm d la ar m tu l l t of l c te m e l w th m les d s l ed g es Whe m gma b ght t th rf c fr m gı f h gh p e withı th e rth th g es e pand d f rm b bbles ın th fl d la If th s l q kly ge l m y f thes b bbles m y b t pped t f m h ghly p k

Th t mp t e f l q d la a ges w dely b t g lly t d n t c ed 1200 C. La poo ın l a (b lt) r th m t fl d d m fl w d wn ry g tl l p f m m l The H waı fl w d mm ly at t f b t 2 m l p h S l h l (rhy l t) a e h hly Th y m l wly d f l t l h rt d t A l l t b mes m d th t f fl w d R p d c l

Fixed fuel storage and pumping areas are ordinarily located on the opposite side of the launching stand from the oxidizer area for safety In many systems the more dangerous and corrosive propellants are handled and transferred by means of specially designed trailers Even liquid oxygen may be transported in field trailers with their own pumping and pressurization systems and introduced into the system through a loading manifold Both fuel and oxidizer systems may usually be operated remotely from the blockhouse

A method of dumping propellants is usually provided Liquid oxygen may be dumped into a concrete evaporation pond or a cleared area remote *from the launch complex Fuel is rarely dumped on* the ground but is either fed back into the storage tank or piped to a fuel holding pond where it can be later disposed of by tank truck More elaborate closed systems are required for highly toxic or otherwise dangerous propellants

General support For static test firings large amounts of water are necessary to cool the flame bucket or flame deflector For the Atlas and Titan missiles as much as 30 000 gallons per minute (gpm) must be provided for a period of 3–5 min It is possible to launch a missile from a dry pad However the dry flame deflector whether it be steel copper or concrete can withstand only a few seconds of flame impingement

Electric power Two independent power supplies are desirable in the launch complex The first sometimes called critical power is accurately regulated with regard to frequency and voltage in addition to being derived from a local independent and highly reliable source Its primary purpose is for instrumentation but it may be used in case of emergency for those operations necessary for system shut down such as emergency defueling depressurization of tanks and tower erection

The second source of power referred to as utility power usually carries the heavy motor pump air conditioning and other load required in the complex Because of the intermittent operation of some of these loads line regulation is not usually maintained as precisely as that of critical power

Power requirements vary depending on the missile system A typical intercontinental *ballistic* missile (ICBM) complex may require 500 1000 kilovolt amperes (kva) each of critical and utility power An emergency generator may also be provided to furnish a few hundred kva for standby

Pressurized gas supply High pressure gas systems (helium nitrogen or both) are necessary at the launch complex for liquid propelled missiles Pressures in the vicinity of 5000 *pounds per square* inch (psi) are used in storing the gases which may be used at somewhat lower pressures of 2000 3000 psi There are two methods of filling the gas storage bottles the gas may be pumped up to this pressure by a multiple stage compressor or in the case of nitrogen the liquid nitrogen may be pressurized to 5000 psi and vaporized at that pressure into the storage tank

These high pressure gas systems must be kept clean because the gas comes in contact with the interior of the missile directly or indirectly through the propellants The gases must also be kept free of moisture because contact with cryogenic fluid would result in ice formation in valves and regulators *Also the presence of oil in the gas might al*low hydrocarbon contamination of the missile or the support system Such contamination could result in an explosion when in contact with the oxidizer

Timing and communication Because events particularly those telemetered and recorded must be accurately time correlated in a test situation the *launch complex must either accept externally generated* timing signals or generate timing signals referenced to radio transmissions from station WWV or other standards In the usual case where the blockhouse is situated on a test range the complex will simply provide for connection to an external timing system

Communication is a serious problem during test and preparation An adequate operational intercommunication system is necessary both within the launch complex and to supporting areas Even with excellent communications equipment the reaction time of personnel is too long for certain decision making requirements Automatic sequencing equipment is widely used to provide programmed relay closures measurements and comparison In this way information for many important decisions may be obtained quickly

Combined erector and tower There are of course many variations of the sophisticated system described above In some cases the erection of the vehicle is accomplished by a crane attached to the service tower and a suitable trailer to transport the missile and offer longitudinal support during the lifting operation In other cases the service tower itself may serve as a retractable erector which receives the missile while lying in a horizontal position and then raises it to the vertical While in the vertical position the erector functions as the service tower (Fig 8) When preparations are complete the work platforms are opened and the erector is returned to the horizontal position for firing Variations may exist also in the methods and height

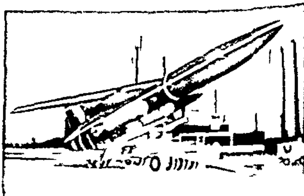
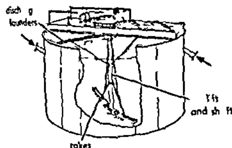


Fig 9 S k ze o f gth l ch r



Fg 1 Do g t r (F m W L & dg d J T Ba ch l trod ct to Ch m l E g g M Gra H ll 1955)

f a g en t tal am unt f sol t and al re- h t nger fi l extr ct

F b th wa h g of pre pitates which ca ot be l ched at facto il in a t nk the Dorr gita t r h wn i Fg 1 i oft u d Th unt i a rti l ta k equ pped ith a lowly tati g rake in th bott m which mo es ettled ol d to th centr f the t k The a ir lift the tub f hich cts also a the haft for the k l fts lu ry t the l d r wh ch l r tate with the h ft Th l der d t ib t th s l d er the t p f th l q i d, so the l y ttl s th ugh the l q u d f r dd tio al t b the l e t After d fi t time the e ti e b t h i pumped thr gh filt to p te th sol d nd l qu d

Continuous countercurrent leaching Bat h l t nk le hing ha two d d t ge Fi t the o t f rem g the ol d a d h rg ng th t k m y be h h a d c d e th r th ce t t n f the fi al ext a t low r on de bl n xtra ted solut r ma in the l ached l d The fi t l mitat n i mi m ed by th u f t q pme t in wh h tl s l d a d liq d both m d m h ally d th e nd d ffi ulty ed by the u f ere of le h tank a d the c t rrent fl w f l e t th o gh th t k n er d t the flow of l d In th ay th mo t early xha ted s l d ext t d with fr h ol ent nd the fre h l id is in cont ct with th m i t c n e trated leach l t n

The c ntı c ou t rcurr nt m tl l i e ı cially effecti e in th wa l ing f pr ıpitat F r tl a erie f tl ick r ı u ed (s THICKEN ING) Tl e fl w liagram of an ex mple f tl ı s t m ı h w in Fig Tl e purpo e f thi pl nt t make a l ition f u tic oda in water l the a ticizati n of da b l y the reacti n



$$Ca(OH) + Na\ CO \rightarrow 2N\ OH + CaCO$$

Tl e rea t n ıt lf ı cond ı ted ın tl three mix ı g t nks l own at tl left ha d end of th flow diagr m Tl es ılt f tl e ch mi al act on ı tl e f rmati n f a lu lge f CaCO u ı n led ın a o- luti n of c n ntrat n b ıt 10% N OH Tl tır rea t n mixt re fl w t the lau der of tl left hand th k ner n wh h ıt ı parated ı to a l o e fl w of 10% luti a d a CaCO ludg a rying a c n id ral l am unt f the soluti n w th ıt a adheri g l q ı d The l dge ı c tinu ı ly pumped l y d ph r gm pump t tl feed launder f th middl thı kener ın which ıt ı mı ed with dil te l t n fr m the r ght l nd thı k n Th fl w l tı fr m tl e m ddl th ken r n w rryı g m t f th NaOH l o gl t ın with tl l dg f m th left ha d u t ı t d re tly t th a t git t r t f rmı l w t r f r th r a t n and f th fi al 10% luti rfl ng f om the l ft l d th ke l th right l n thı k ner th l lge fr m the middle thı k n r ı gı a final wa h w th f esh w ter nt ing fr m ıt d Th l dg d harg d fr m th ı thı ken arly fr l ca tic od Add t n l th k n ma be added t the y tem if t ll m re th gl wa l ı g f tl lıd ı d ıred

Wh n the l d an larg l mp r when th t of l t ı l w ıt t pr t l l t m the l d f m t nk t t k Then a modifed c t r r nt meth l lled a Shank y tem a dif f n batte y ı u ed Thı m thod g es th eff tı u f l nt and th w ll-e tracted s lıd of the nter ur nt m th d The p ı cipl f th

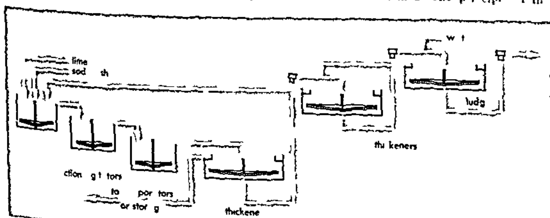


Fig 2 (b) C y t t ct sy t m (F m W L & dg d J T B h l t d t t Ch m ıcal E g ne g M G w H ll 1955)

ing as at the surface of a flow promotes the forma tion of glass Slower cooling as near the center of a flow favors the growth of crystal

During many volcanic eruptions the lava is so rapidly ejected that it is blown to bits by the ex plosive force of expanding gases The mall ma es rapidly congeal and settle to the earth to form thick blankets of volcanic tuff and related pyro clastic rock Lava flows and volcanic tuffs cover large areas of the earth s surface and may form more or less alternating layers totaling many thousands of feet in thickness *See* IGNEOUS ROCKS MAGMA PYROCLASTIC ROCKS TUFF VOLCANIC GLASS VOLCANO [C A CA]

Layout drawing

A design drawing or graphical statement of the over all form of a component or device which is u ually prepared during the innovative stages of a de ign The detail and completeness of a layout drawing are not adequate to ensure a faithful explanation of the device and its construction to any but such individuals as designer and draftsmen who have been intimately involved in the conceptual stage In a sense the layout drawing is a running record of ideas and problems po ed as the design *takes form and evolves In the layout drawing for* instance considerations of kinematic design of a mechanical component are explored graphically in incomplete detail with only those aspects being stres ed for which graphic portrayal of the ele ments and their interrelation hips would contribute to the evolving design

In mo t ca es the layout drawing ultimately be-comes the primary source of information from which detail drawings and as embly drawings are prepared by other draft men under the guidance of the designer *See* ENGINEERING DRAWING

[R W M]

Lazurite

The chief mineral con tituent in the ornamental tone lapi lazuli It cry tallize in the i ometric sy tem but well formed cry tal u ually dodec ahedral are rare Mo t commonly it is granular or in compact mas es There is imperfect d dec ahedral cleavage The hardne is 5–5 5 on M hs cale and the pecific gravity is 2 4–2 5 There is vitreou lu ter and the color i a deep azure more rarely a greeni h blue Lazurite is a tecto ilicate the compo ition of which is expre ed by the f r mula Na_4Al_3Si O_1 S l ut ome S may be replaced by SO_4 or Cl Lazurite is solul le in hydr chl ric acid with the evolution of hydrogen sulfde S e SILICATE MINERALS

Lazurite is a feld path id but unlike the other meml er of that group i not found in igneo i rock It occurs exclu ively in cry talline lime tones as a contact metamorphic mineral Lapi lazuli i a mixture of lazurite with other ilicates and cal ite and u ually contain di eminated pyrite It ha l *ng* l een valued a an ornamental material Lazu rite wa formerly u ed a the l lue pigment *ultra* marine in oil painting Localities of occurrenc are in Afghani tan Lake Bikal Siberia Chile and San Bernardino County California *See* FELD SPATHOID [C S HU

Leaching

The dis olving by a liquid olvent of oluble ma terial from its mixture with an in oluble sol Leaching is an industrial eparati n operati based on mass transfer Example are the wa hin of a oluble alt from the urface of an in lubl precipitate the extraction of sugar from uga beets of oil from oil bearing seed of metal an their compounds from crude ore and of tann from tanbark The olvent may be cold or hot wa ter as in the wa hing of a precipitate or the leach ing of sugar beets it may be a pecial organ *solvent as in the extraction* of oil *from* eed o it may be a chemical olution as in the extracti of copper compounds by aqueous amm nia

Leaching is closely related to olvent extracti n in which a soluble substance is di olved from on liquid by a econd liquid immi cible with the fir Both leaching and olvent extraction are ofte called extraction

The rate and mechani m of leaching depen *upon the structure of the* olid *and the di tribu* tion of the solute in or on the solid One extrem is in the wa hing of a precipitate where all the lute is on the surface of the olid and i alread di olved in the solvent adhering to the particle In this a e olution is rapid and i complete a oon as the olid and olvent are well mixed as slurry Another extreme i found in the leachin of egetable matter uch as eed or l eet wher the olute i l ehind cell walls or therwi e *int* mately di per ed throughout the lid truct re Then l ecau e the ma tran fer i l y the sl proce e of lid diffu ion and o m i c n ider able time mu t be allowed for the extraction A other ituation is found in metallurgical leachin where the metal i finely di per ed in the ore Th ore i then u ually cru hed l efore leaching to fre the metal fraction for interaction with the l ent

Batch leaching The kind f equipment u e l f leaching al o depends on the tructure and parti l size of the oli l Relatively large lump of s li are treated in imple ertical tank equipped wit perforated fal e l ottom The fre h s li l i place in the tank and solvent p ured over it The extrac drains through the fal e l ott m to the l tt m the tank An xternal pump may al l e u ed t circulate olvent fr m th l tt m f the tank l a l to the t p f r additi nal pa thr ugh the l ed olid Wh n the l ent and s li l are in eq ili l rium the liquid called the extract i drained th extracted li l di carded and an ther l at l charged t the tank

A more eff ti e u e f ol ent i ol tain l l di i ling the t tal l ent into eral e ual frac ti n and u ing each fra ti n parately with a drain t th end of each treatm nt All xtra t ar *th n coml in d Th i give a m th ro gh l ach*

Germ French Morocco S uth We t Africa and Spa n. M t of th l d p d ed n the United States is mi ed in M uri with additional l ad com g fr n the estern tat Id l Utah Ari m a. Col rado d Mo tan

Lead r ly occurs in it el mental tate Th m t comm o e is th ulfide gal na Th ther ner l f omm ial imp t c are the bo t eru te a d the lf te angl te which emu h m rer re

L d res g nerally occ n nat re ciate l th l er d zi Beca e of it rrence w th l er lead ha th pa t b n con dered a b prod t f l e min g Oth metal m monl occu ing ith lead e ar pper nic tim y d b muth M t of the w rld p d t n of r ic a t m y a d bi m th arl es from th sep r t fr m le d or

Comme l l d es may co tain a l ttle 3% l d, but a l ad c nt t f b t 10% i m t c m m Th es c c t ated to 40% or greater le d c t t b f e melt g A var ty f m l ni l sep r ti n p oce es m y b empl yed f the ce t at f l ad res b t the ulfide r gen r lly c t ated by flotatio proc s e f r b h the r partcul ly table S e LEAD METALLURGY

M e th th d of th l d p d ed n th U ted St t s i der ed f m recl imed l ad l d ll y The h f our e f th s nd ry l d is sc pped t m b le t g l tter The dary l ad bta ed by m lti g of rap a d is ge lly t p fied b t the e r ed l d lloy Sec dary le d l m t ag b tte s n t m nt m nd i r u ed i b tte y m u f ct r Th le d c p h h c ta t re- sed i them n f ct e f ld

Uses A mpl ed i th d cu n of cr p l d bo e th l gest le u e f lead is fo th ma u f ct r of to ge batte es Oth imp rtant p- pl c n e f the m nuf ture of tet aethyl f d, c ble ov g tru t n p gm nts s ld r d mmu tio

Th l d t ge batt ry n t f g t plat f p l ad a p t pl te f l d p r x d d n l et lyt of ulf d lut Th plat a e mad by c t g pe f t d grd f m an ll y f le d c tai g 7 12% ant m ny d small m t f ti The a t m y s dd d t gi the gr d bett h dn s d c osi re t e h th t add d t giv bett ti g p pert e The e t g d i ted with p t f l tha g (PbO) m tu f l th ge nd fi el d ded m t ll c l d The p t e gr d i ted w th a m xt of l tha ge nd fi ly d ded l ad d m som e ed l ad (Pb O) Aft th b tt e e a mbl d and cha g d w th s lf r d the pl te ar f m d by p i g lect tr nt th gh th m t t th l d d at th gat pl t t fi ly d d d l d po ge d c n ert th lead d at th p t e pl t t l ad p id Th ch m al r ct wh h t k pl n b rging r d h rg ng a battery are ery mple l t may l e indicated i mple f rm l y the f llowi g q ati n

$$PbO_2 + H_2SO_4 + Pb \underset{Ch\ rge}{\overset{D\ schar}{\rightleftharpoons}} PbSO_4 + H_2O$$

Be i e ulfur c a d i c n umed h harg of the l att ry the sulf i ic d c ncent at n i used a mea re f t e tate f l a ge f l a l l tt ries

In 1957 an import nt add t o t th fam l f l ad l atter was tl i tr lucti n f a l arg al le dry c ll The l tt ry i c mpo ed f an alkali l ad de-s lv r s tem and i apal l of repeated d h g and re l arge wit t aff t g it capac ty Also n tew rthy ar t op r l ility t both l w and high temperatu re and its l ng term h lf life S STORAGE BATTERY

The ma lactur of t t ethylle d i the ee nd larg t e f l ad Wl n 2 3 ml f thi antiknock age t are dded t l gal l ga li e the oct ne r t ng of the fuel i ra ed al t 10 tane n mber Thi increa e n o t e n mb permit the i e f high r c mpre i n rat o in aut m l ile eng ne the eby mpro ing gin eff i ncy F r e mple t ha b en h wn that n a age dec ea e i g l c n mpt n f l t 45% can l e ol ta ed i g t g fr m 5 25 1 t 10 1 mpres i n ratio der nditi n f n t nt perf rmance S ANTIKNOCK AGE TS INTERNAL COMBUSTION EN GI E

T t a thylle d ma ufa tured by the r t on f thyl hl de with n all y f odi m and lead Th h mi l r a ti n s

$$4PbNa + 4C_2H_5Cl \rightarrow (C_2H_5)_4Pb + 4NaCl + 3Pb$$

Lead is melted and mix d with od m t f rm n all y nta ng abo it 10% sod m The l d ll y tre ted with ethyl hl ide n ut cla at m le at t mp rat re nd pres re i the h ence f l e t The crude p od ct i p r t d by team d t ll ti nd i pu f ed by a bl wi g to remo e g c b m th mpound a i g f m bi muth imp t e the o ig al lead met l The t traeth yl l d i th n blended w th thyl d hl ide d ethyle d b om d wh h erve a a e ge s t d the r m al of le d d p it f m eng es It ld n thi f rm t p t l um efi r a ti k ck fl d f r dd ti n t th it a t mot g - l ne t ks In a t n g l ethylen dib om de al n ed s the s ven er

Be u f it e clle t s ta e to c r s on le d find xt ns e i e i c n t u t partt cl ly i th chem al i du try It is e i tant t tt ck by many a d be au it f rm it wn pr t t e xide c at g Bec u e of th ad nt g u char a ter t l d i u ed w dely n th manufacture d ha dl g of ulfu i c d Th c r s on re s t e f le d l ut l zed in th e th d c p o- tect of metal t tu e Thi s ompl hed by mp ng lectr h ge n the t uct re t b pr t ct d the tru tu re as the th d lead the a d S h pr tecti u eful f la g t ct e s h s hips p p l s and b dge S e COR OSION

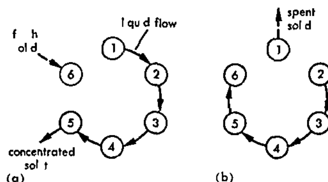


Fig 3 Countercurrent leaching by Shanks system (a) Beginning of cycle (b) First step in 6 step cycle (From R E Treybal Mass transfer Operations McGraw Hill 1955)

Shanks technique is to retain each batch of solid in the same cell or extractor during its entire leach but by appropriate piping to change the flow of solvent periodically in such a way that the charge in any one cell is treated with successively weaker solution until fresh solvent is used and then dumping the exhausted solid and charging the cell with fresh solid *The process is shown in* the diagrammatic flow sheet of Fig 3 which shows a 6 cell Shanks system In Fig 3*a* cell 6 is empty ready for a fresh charge of solid The oldest charge is in cell 1 and those in cells 2 3 and 4 are successively younger with the freshest charge in cell 5 The solvent flow is in the order 1–2 3 4 5 This flow pattern is maintained for a definitely scheduled time until the solid in cell 5 has been leached to the desired thoroughness and in the meantime cell 6 is charged with fresh solid Then *the flow is changed to that shown in Fig 3b and* cell 1 is cut out and dumped This cyclic process continue indefinitely

In practice the cells are usually arranged in a straight line instead of the circle shown in Fig 3 The piping is arranged to give the same sequence of operation as in the circular arrangement This reduces the floor area required for the battery and facilitates the use of a belt conveyor for charging the cells from the top The exhausted solids are dumped from the bottom of the cells onto a second belt conveyor *which removes them from the* system Heaters may be installed in the liquid flow system between each pair of cells to keep the solvent hot If the temperature is above the boiling temperature of the solvent at atmospheric pressure the system is operated under pressure except when the cells are being charged or discharged

For more difficult leaching operations especially of oil bearing seeds several rate systems highly specialized for the specific individual application have been developed *See* MASS TRANSFER OPERATIONS SEPARATION (MECHANICAL) [W L M]

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Lead

Chemical element number 82 lead Pb is a heavy metal (sp gr 11 34) with atomic weight 207.21 Lead has a bright bluish color which tarnishes to a dull gray It is pliable inelastic and easily fusible melts at 327 4 C and boils at 1740 C The normal chemical valences of lead are two and four It is relatively resistant to attack by sulfuric and hydrochloric *acids but dissolves slowly in nitric acid* Lead is amphoteric forming lead salts of acids as well as metal salts of plumbic acid Lead forms many salts oxides and organometallic compounds

Industrially the most important lead compounds are the lead oxides and tetraethyllead Lead forms alloys with many metals and is generally employed in the form of alloys in most applications Alloys formed with tin copper arsenic antimony bismuth cadmium and sodium are all of industrial importance *See* LEAD ALLOYS TETRAETHYLLEAD

Lead compounds are highly toxic and lead poisoning was at one time a common occupational disease The greatest industrial hazard arises from the inhalation of vapors or dusts of inorganic lead compounds In the case of organic lead compounds absorption through the skin may become significant Some of the symptoms of lead poisoning are headache dizziness and insomnia In acute cases there is usually stupor progressing to coma and terminating in death With proper precautions however industrial lead poisoning can be entirely prevented *See* TOXICOLOGY

Lead is one of the oldest known metals and the earliest archeological specimens date from about 3000 B C It is mentioned several times in the Old Testament and in ancient Egypt it was *used to* glaze pottery and make ornamental objects Lead was used extensively by the Romans for water pipes even to the extent of being standardized by size and length

Natural occurrence Yearly world production of lead is about 2 000 000 tons The leading countries in lead *mining and production are* Australia the United States and the Soviet Union The United States is unique in that it consumes much more lead than it produces (about 50% of *the world's consumption*) *Other important sources* of lead are Mexico Canada Peru Yugoslavia

Type metals Type metals contai 94–1 % ti nd 2½–25% antimony Antimony incr a e hard ess a d red es hri kage d ri g ol dificati n mp o es fl dity and reprodu ti n of d t il oth el m t lower the melt ng tempe at re f i ll y C mmo ly u ed type metal melt at 460–75 F

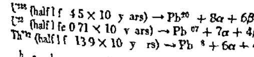
Bearing metals Lead bearing metal (l abbitt metal) co ta n 10-15% ntim ny 5-10% tin nd for some appl c t m ll am unt of ar en r c pper T d ant mony c mbi to form o po d wh h p o ides we r res ta c These ll fi d f eq e t applicat on in ca t leeve l ear ngs a d eu ed t n ly fr ght ca j urnal earing In m a t bea i g b on es th lead o t tma e eed 25%

Solders A la ge n mb of lead ba lde r p n s ha e been de loped M t ntain l g amo nt of t n w th elected mi or additi n t p vide pec fic be fit su h s impro ed wetting har cter st c

Free-machining brasses bronzes and steels Le d s dded in m nts fr m l t 25% t bra es a d b zes to impro e m ch ning ch acteri t s Le d eman d c ete p rt cle i the e alloys It is also added t some co t u tion l steel prod ct t in rease ma h ab l ty Only bo t 0 1% i needed but th to g in l ed i la ge that th f rms an impo t t e f r l ad S e ALLOY LEAD LEAD METALLURGY SOLDERING TI ALLOY [D N W]

Lead isotopes geochemistry of

Th study of the i t p c mpo t n of l ad i mineral and rocks n ord r t el te it to p st as-soc t s of th le d w th u i m and th rium Lead h f u i topes f rel tive ma 204 206 207 d 208 Pb Pb a d Pb a e prod c d b th d o ti d ay f u an m nd thor um Th dec y relat are



U^{238} (half l f 4 5 × 10 y ars) → Pb^{206} + 8α + 6β
U^{235} (half l fe 0 71 × 10 y ars) → Pb^{207} + 7α + 4β
Th^{232} (half l f 13 9 × 10 y rs) → Pb^{208} + 6α + 4β

h e d te lph part l (doubly cha ged h l m l) a d β den tes beta p rt cl (lectr o) F g en y t m h m ne l o ock *prim ry* l d i defined s th l d p es-ent n the t m t the t m it wa formed R d g l d is l ad p duc d in th tem b the d f um d th r m t w *formed* e Pb t p d ed b the d cay f ny nat lly oc r i g r d ct pe t c n be used d t d t rm the m t l pri m ry le d a y t m P m l ad w ll l de Pb ll l th Pb nd bl mo nts f Pb Pb a d Pb d p d g th rigi f the l d

Fort n t ly omm r k u h a gr nit s a d b lt *y t m l k* th ru t f the rth h e fficientl high r t f th im d a um to le d t e m bl ch g th ot p rmpo t f the l d t m nt rval s h rt a ome ten of mill n of year S me m n erals ha e practically all rad genic lead wh le th ers ha e u f l w rati s f ura ium and th ri m t lead that the i ot pic c mp it n of th ir lead will n t h e hanged appr ciabl y er th u ands of milli n f y a S n e the i *otop c c mpo iti n of l d ob rved in ro k* and min al i r lated directly to the am unts of urani m and th ium th l d w a oc ted with in the p t and the length of t me of the a iat n it i f il le t gai in format on f om coo dinated st idi of the geochem i try f urani m thor um d lead wh h c uld n t be obta ned f m elem nt wh l are n t in l ed in r dioa ti e d av h in Some example will be gi en t illu trate the uniq e al e of thi type of n est gat n

Variation with time If the uran im th rium and l d ntent a d lead i t pic c mp tion re known f a p rti ular min ral it s po ble to lculate the i topic c mpo ition of the le d at ny t me in th p t if th min ral r pre ent a l ed sy tem A cl ed sy tem i one in whi h the ur nium lead and th ium lead rati ha e n t been ch nged in th pa t l y proces s ther than radio-a ti e decay th t i the r tios we e ne r ha ged by h m cal pr ce es It i p ble in prin ipl to treat th o t r porti of the arth a a geol c sy tem a d t t dy the isot p c compo-sit n of it lead a a f cti n f t me Meani gful esult an be bta ned p vid g the u an um lead a d th r um lead r tio a e rea ably u if rm th ough ut the y t m r if ampl ng i ten i n gh to a er g t the local a iations which m y e it I e ther c s it p sibl then t de term ne the ura i m l d and th r um lead ratios of the y tem prod cing the lead

Th t me var t n has be n tud ed in tw dif fe nt urces pota um feld p r a d gal na Po-ta m feld par (KAlSi O + NaAlSi O) is omm n m n r l i ig e u rock s ch s gra te nd p gm tites Galena PbS mm l c u s i e n f hydr thermal o igin Both mine als ha e h l w uran m le d a d th rium le d r tio that th top mp iti n f the r l ad will not have hang d app e bly s n e th time f cry talliza ti n p o ding th re h bee no o t mi ation f m e t rnal r es Alth ugh pota si m feld par nt i rel t ely mall mo nt of lead (5–100 ppm) t h the gr at d ant ge th t the t m f f rm t f the m e l an b a c r tely d ter m ed by m n the ge of cogen t m e als h a m a ran nite zi n *Se* ROCK (AGE DETE MI ATION) On th th hand, th *e ns f om* wh ch g le a i bta n d do n t rule nta mi al wh h are s tabl fo ag *det rm nat on* th t the t me of f rm t on f a gal na mu t be nf rred fr m ge r l ge logical el t ns S nc l ad a ly bt ned from g le a much m re d t x t f r t th fo igneo *m neral* although th d t gi n by the latt r b t rp ted w th gr te cert nty

Th t p c c mp ti n f lead h been de term ed f r en pot s m f ld par of k n

Because of the poor structural strength of lead it is generally used in the form of its alloys particularly in combination with antimony or is u ed as coatings or plates on stronger structural metals Tin alloys are frequently used in protective plates to impart mechanical strength and better corrosion resistance To some extent the lead that has gone into the usual architectural and plumbing applications in the past such as roofing and flashings for example is now being displaced by other material However this decrease in basic architectural uses is being offset increasingly by growth in specialized uses

For example lead has long been used as protective shielding for x ray machines Because of the expanded applications of atomic energy radiation shielding applications of lead have become increasingly important Basically shielding effectiveness against radiation depends on density and lead has the highest density of the commonly available materials Wherever glass windows are required in radiation equipment a type of glass containing large amounts of lead is used *See* RADIATION SHIELDING

Lead has long been used in construction becau e of its vibration damping properties Heavy machinery and even large buildings are isolated from vibration by placing them on pads of lead In inertial guidance research the experimental chambers are isolated from adjacent ground and structures by the use of mas ive lead pad

Lead sheathing for telephone and television cables continues to be a sizable outlet for lead The unique ductility of lead makes it particularly suitable for this application because it can be extruded in a continuous sheath around the internal conductors The lead u ed in this application is generally alloyed with small amounts of arsenic and bi muth

The use of lead in pigments has been a major outlet for lead but is decreasing in volume White lead $2PbCO$ $Pb(OH)_2$ is the most extensively u ed lead pigment It is prepared from metallic lead by treatment with acetic acid air and carbon dioxide It is an excellent pigment l ecau e of its out tanding chemical affinity for paint vehicles and it great hiding power Pigments such as red lead (Pb O) and blue lead (a coml ination of l asic lead ulfate PbSO PbO zinc oxide and carbon) are u ed as metal protecti e pigments in paints Other lead pigments of importance are basic lead sulfate and lead chromates The lead chr mates are frequently u ed as dyes in formulating yellow orange red and green paints *See* I IGMENT

The high density of lead which permits a maximum of striking power with a minimum of air re istance has made lead the ideal metal for l ullets and hot Lead shot i manufactured by a unique proce s which invol es dropping molten lead into water from height up to 125 ft thu freezing lead in the spherical form a sumed l y it droplet

Principal compounds A con id rable variety of lead compounds such as silicate carbonate and salts of organic acids are u ed as heat a d light stabilizers for polyvinyl chloride pla ti s These compounds are both inexpensive and effective They function as hydrogen chloride acid acceptors thereby preventing the autocatal tic breakdown of the plastic by the acid

Certain inorganic lead compounds find pecialized use I ead silicates are u ed for the manufacture of glass and ceramic frits which are u eful in introducing lead into glass and ceramic fini hes Lead azide $Pb(N_3)$ is the standard detonator for explosives Lead ar enates are u ed in large quantities as insecticides for crop protection Organic insecticides have displaced lead ar enate t some extent but not completely becau e they ha e not been found as effective in certain applicati ns

[ILSH I D JO]

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Lead alloys

Substances formed by the addition of one or more elements usually metals to lead Lead alloys ma exhibit greatly improved mechanical or chemi al properties as compared to pure lead The major alloying additions to lead are antimony and tin The olubilities of most other elements in lead are small but even fractional weight per cent additi n of some of the e elements notably copper and arsenic can alter properties appreciably

Cable sheathing alloys Lead is u ed as a sheath over the electrical components t protect power and telephone cable from moi ture All ys containing 1% antimony are u ed for teleph ne cable and lead arsenical alloys containing 0 15% arsenic 0 1% tin and 0 1% bi muth f r example are used for power cable Aluminum and pla tic cable heathing are replacing lead alloy heathing in many applications but improvements in method of applying a lead sheathing (continuou extru sion) may off et this trend somewhat

Battery grid alloys Lead alloy grids are u ed in the lead acid storage battery (the type u ed in automobiles) to support the active material com po ing the plate Lead grid all y c ntain (1 % antimony for strength small amount of tin to improve castal ility and ne or m re other min r additions to retard dimen i nal change in servi e No lead alloy capable of replacing the lead antimony alloys in aut m l ile l atteries l ave been developed although re earch in thi area has l een extensive An alloy containing 0 03% al i im f r u e in large stationary l atterie ha met with s m succe

Chemical resistant alloys I ead all y are u ed xten i ely in many applicati n requiring re i t ance to water atm ph re r cl emi al c rrosi n Lead all y are noted f r tl eir re i tan e t atta k l y ulfuric aci l All y mo t comm nly t l contain 0 0% pp r or 1 12% antim) wl re greater tr ngth i needed Tl e pr n f a ti m ny l were corr i n re i tan m l gree

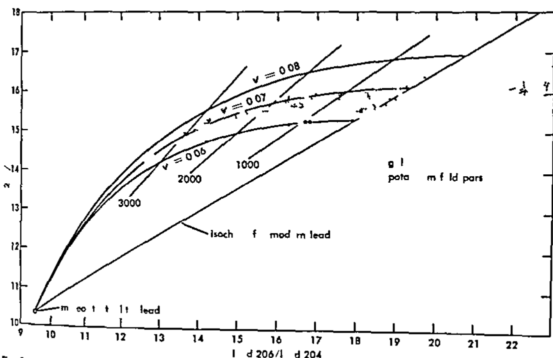


Fig 2 Pb 06/Pb f ct f Pb /Pb 04 t m hyp th t c l f o m ts. Th fo lead fr m g l d f ld p rs Th g f th g wth rv l l t d f u U /Pb earth tak 4.55 × 10 y a D g l l t m g cl d yst m p t th t m f isoch = U /Pb (t m t) at th p se t lead pa t

a d Pb 08/Pb ti f y l d w ll determ ts mod l g

The mod l ge bas d a mb of s mp- t s, th m t t ingent b g th qui m t f a losed syst m the c t m t p t the tim f p t n f th l d d b ce of tami ti f th l d with l d f d ff ent g aft par ti n It n t s p g th t these c diti n t alw y m t (ee f ll w g ct in this arti l n a mal u l d) I f v bl cases, m d l g agr e w th th g s of s p posedly co t mpo eo oneo ock w th ±100 × 10 y bout th l m t f ccu y f th m thod Th method b tt s t d f d t ngu h ing b t en tw le d f gr tly d ffering g th than f d t rm g p c g F ample, i th App l h an M t g l n f m Precambrian ock t F klin N.J gi a m del g f abo t 900 × 10 y ars wh l g l a o- ted with P leo k e l l l tes g mod l ges f 100 t 300 × 10 y a Th l tt gal w p b bly empl c d d ri g m ph e f th f rm ti n f th App l hi M ta b lt, hil th P amb n gal nas w e f rmed p t th App l h s.

F gu e 2 ggest th t l d n g l de ed f m sour n ir nm t wh h h m l d rat s t d ff ri g g tly f m th wh h p o d th l d f d i gneo k The l d ge sot p gr wth c rv f r th gal p h p a ting a l ghtly high u m l d ti n

th e fo th g l n lead An ther po ble a f this d ff ce i g en b l w i th sec t n omal g lena Also m e analy es f f ld p lead m st be mpl ted t cert i whethe th p esent d ta prope ly hara ter ze ig ne us r k The feld pa dat are ll f m N rth Am i a wh l the gal na dat ar fr m all c nti ne ts e pt g Ant t ca H wever th e s e de ce f t f om c t t to th the g l na d t It str ki g th t th ga l a l ds f m h a cl s ly d fined c rv s c th y p t mples t k m tly at random o wo ld w de cal

Anomalous leads Th e l d gi e mod l g wh h re l ly rrect. For i ta ce if the mod l ed t d t rm ge s or e t, l ad h uld b f nd t th right of th mod n l ad och n F g 2 (n gati mod l age) F gur 2 d e n t co th f ll r ng of an m l u l ad Pb /Pb t s high 93 d Pb /Pb 04 ti h gh 24 h bee b rv d Th s trem h wev A m l le d ar ge lly h t d by h gh Pb 06/Pb and m t mes by h gh Pb /Pb t o w ll Pb /Pb m y n t b h gh n the ab n dan f U so l w th t ly gl g bl m unt of Pb h be n m d w th espect t Pb r th p t 2 × 10 y N te that th Pb /Pb rve F g 1 ne ly fl t th t tim t rv l

A gn fica t f tu f al l d th t th sot p mp t n s n d bly f m

40 30 20 10 0
lead-208
lead-206
lead-207
5 4 3 2 1 0
t m b llion of y a s ago

Fig 1 Isotopic compos t on of lead in igneous ro ks as a funct on of age

age covering a tim span f fr m t 27 × 10 years The rati s f I1²⁰ I1² and Ib² t I1² ⁴ are pl tt d a a fun ti n f ag in Fig. 1 The experimental un ertaint in th rati s are ±½ to 1 of the rati thus the variati n are many tim s th errors It is seen that the m re r ently a f ll par was form l th more I b²⁰ I b² an l I1² it contain with re pect t I1² ind atin an a cumulati n f ra i geni l ad in the s urce environment All points in Fig. 1 repre sent f ll pars ex ept th e at 0 an l 4 × 10 years Th points at th pre ent (m d rn primary lead) repre ent the range in i topi c mpo iti n f l a l fr m three ba alt a gal br e l clay fr m the Pa ifi O ean an l 2 mangan e n dul fr m th Atlantic an l Pa ifi O ean Th basalts an l the gal r pr bably riginat l fr m partial fusi n f sili ate minerals at great d pth in th earth D fining the ru t a th r gi n above th M h o ovi i di ontinuity whi h has a d pth f ab n km un l r th c ntin nt an l 10 km n ler th ocean an l th mantle as th regi n b etw en th M h rovi i lis ntinuity and the b un lary f th c re at 2900 km ba alts an l gal r s riginat fr m th l ep crust r uter mantl Th r l lay an l mangan e n dul n th th r han l r pre ent a ampling f l a l fr m a larg n mber an l variety f s urce n th surfa f th earth Th r l a l may thus r pr ent a rea nabl a erag f r the i t pi c mp iti n f l a l at th earth rfa e t day N t that th ceani an l ba alti l a l hav p t imilar i t pi c mp iti n Thi in li at s that averag surfa e l a l i n t greatly diff r nt in i t pi c mp siti n fr m l ad f d ep at l ri gin

Th points at 4 × 10⁹ year r present l a l in tr ilit FeS fr m tw r n met rit Th tr ilit c ntains so littl uranium with respe t t l ad that th i t pi c mp siti n f it l a l w ul l n t l a chang l m asurably in th la t 4 × 10⁹ y a th presently a cept d ag of th arth 5 Fars (AGE OF) The data fr m ign us r cks is b dly c mpatibl with th a sumpti n that th i t c mposition of t r trial l ad 4 × 10⁹ year ag is represente l by th tr ilite l ad That i ar 4.5 × 10 years ag with l a l f th am iso c mpositi n as tr ilite l a l it is possibl t select values f r th uranium l a l an l th rium l ad rati s whi h will giv gr wth curves f r th l ad isot pes which fit the observ l data quit cl sely Th al culat l growth curves in Fig. 1 orrespond t pre ent-day rati s in the s urce environment of

$$U^{238}/Pb^{204} = 9.3 \text{ (at m rati)}$$

or

$$U/Pb = 0.18 \text{ (w i ht rati)}$$

$$Th^{232}/U^{238} = 4.0 \text{ (atom rati)}$$

This simpl m d l a sum s that th s ur e env r nment is a cl s e l system in th sense def n above

It is n t entirely l ar just what sur materia the f ll par l a l charact rizes Th f ld pars oc cur in p gmatites whi h were a sociated with pr esses of m untain buil ling in th pa t Th l a may have been d riv l eith r fr m l a l br ught t ward th surfa e from th mantl fr m sedim r whi h were buri l an l m lt l r partially t l ing th pr e r fr m b th f these s ur H wever it has been sh wn ab v that l ad in r ks f d p eat l rigin su h a basalt d es n t d ffer greatly in i t pi c mp iti n fr m l ad in oc ani mat rial whi h are f urfa rigin and ha un l rg ne er i n Thus th curve in Fig. 1 ap pr ximate the past variati n f i ot pi c mp i ti n f l a l in b th th uter mantl an l in the crustal mat rial

Th i t pi c mpositi n f l ad in ev ral hun dr l galenas has b een publi h l S m diffculty ari es in determining th tim f f rmati n f ga lena as alrea ly m nti n l a rdingly a diff nt meth d f pl tting th l a l i u ed Il Il /Il pl tt l again t Il /Ib fr m th urv s in Fig. 1 a n w curv will r sult whi h ea h point rre pon l t a m l l ag f r a parti ular l a l Th m d l ag i th tim at whi h th l a l wa eparat l fr m urani m in th s ur e en ir nm nt Thi tr atm nt may be ex pan l l t all w f r varying urani m l a l rati s in the s urce envir nm nt A um that a gr p gal nas riginat l at a tim × 10⁹ y ars ag fr m s ur en ir nm nts whi h all had th i t pi c mpositi n f met riti tr ilit l a l 4.5 × 10⁹ y ar ag an l whi h w r l sed y tem with diff ring urani m l ad rati Sin e th rati f ra li g ni Il t radi genl Il will be th ar in all th l r gardl s f th urani m l a l rati in th s ur a pl t f Il² /Ib ag in t Il /Il f r th l ad will yi ld a straight li e S h a lin i c n tant m d l ag an l diff r nt uranium l a l rati is call l an is l r n Figure 2 sh w isoc r n f r i rol a d l a l whi h w re separat l fr m uranium 1 2 a 3 × 10⁹ y ar ag F n wl lg f th Il² /Pb

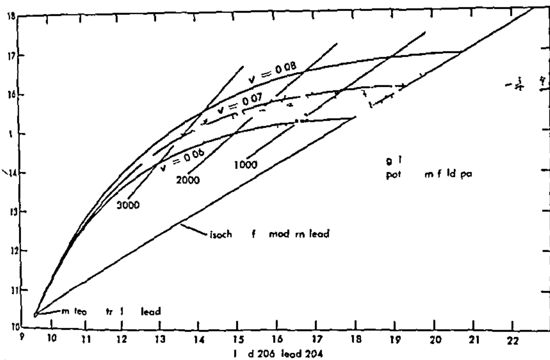


Fig 2 Pb 06/Pb f nct o f Pb /Pb t m i hyp th t c l o c f o m ts. Th for lead fr m g l o d f ld pars Th g f th g owth rve a l l r d f U /Pb earth tak a 4 55 × 10 y rs. D g l l a at a m g cl ed y t m p to the t m f isoch = U /Pb (t m t o) at th pr t le d s pa at

d Pb²⁰⁶/Pb ²⁰⁴ tio f r y lead will det rm ne ts mod l g

The model ge i b ed n a umb of a s mp- ti ns, the mo t tri gent b g the r qu ement of closed y tem in the u c en r m nt up t th tim of ep r tion of the l d nd b n f n tam, ation f the l ad w th lead f a d ff re t g afte sepa t It is ot pr ing that thes c n diti s ar n t alway m t (se f ll w ng secti n in th arti l on an m l u lead) In fa rable cases m d l g gre with th g f s p- posedly ntempo a eo igneo ck with ±100 × 10⁶ ye rs, bout the limit f a cur y f th ethod. Th m th d bett r ted f d t gu h ing between tw le ds f gr tly d ff ri g ag r the th n f r determining p e e ge F ex ample, t th Appala hian M u t s g l na fr m P ecambri rock at F nklin N.J g a m d l ag f bout 900 × 10⁶ y wh le g le a so- ciated with P leozo c k n s e l local t e g e mod l g of 100 t 300 × 10⁶ ye rs The latt galena w p ob bly empl ed d ing me ph f the f rmati n f th App l h n M u t i belt, hile th P e mbri gale s w e f rmed p t the App la hi ns

F gu e 2 ggest that l ad in g l de ed f m so rc nments wh h h e a um l d r tios t d ff ri g greatly f om th wh ch pro- du e th le d f d n gneo o ks Th l d gneou rocks f ll y temat lly bel w th g owt p growth rv f th gal s pe h ps ind at ng a l ghtly h gher r um le d r t n the u e for the g l na le d An ther po ibl au e for th s d fference is g en bel w in the e t o n nomal us gal n s Also m re analy es of feld par le ds m t b mplet d t a cert n wh th th p ese t d t p p ly ch acter z ig e s ocks The f ldsp r data a e all f m No th Am a wh le th g lena d t a e f om all c nt e ts ept g A t r ti a H weve there i no iden e f ri ti n fr m e ti nt t n th r i the gal na data It s t iking that th g l n le d f rm u l a l sely d fi ed curve ce they p e t mples t ke m tly at and m n w rld w d scale

Anomalous leads These le d gi e m del ag wh h r lea ly nc rrect. F stance f th mod l ed t det rm ag s c rr ct n l ads h ld be f nd t th right f th modern l ad so hr n F g 2 (negat model ag) F gu e 2 doe t r the full ra ge of a mal us leads Pb /Pb r t s as h gh s 93 a d Pb /Pb at s s high s 24 h b e ob erved These xt em c es e re howe e A om lou leads a e g e ally h acte i ed by h gh Pb ²⁰⁶/Pb and s m times by h gh Pb /Pb² r t os as well Pb /Pb ²⁰⁴ m y t be h gh s nc th abun da e f U is low th t ly n gl gible am nt of Pb h s been mad with pe t t Pb th pa t 2 × 10⁹ y rs N te th t the Pb /Pb urv n F g 1 n rly fi t o th t tim t rv l

A gn fi nt f at e f anomalo l d th t the t p mpo t es c d ably fr m

T bl 2. I otop c composition of l d l a gr lt and oci ted pegm tit

So rce f l d	At m rat os		
	Pl/Pb	Pl 07/Pl 20	Pb/Pl 20
C tod y	0 3	15 7	48
C t 10 X10 y rs go	16 4	15 4	30 0
G perth t	18 6	15	39 5
Gra te, pl gnocl se	18	15 5	40 0
P gm t t perth t cry t l	16 8	15 3	36 0

The u tum le d ti f nd for th gra ite p es l l ted Pb 06/Pb a d Pb /Pl t os n the ock 1 05 × 10 y rs ago whi h ag rath r cl ly th the t pic mp ti f l d i the feld p cry t l n a p gm tite Th could i d te that th ro k as wh l l ly p- p um ted a l ed y t m s c it wa form d th respect t r n m Pb nd Pb H w e a m'l r te t f the Pb /Pb r tio h w th t th g a t a n tha e be n a cl ed y tem f th rium a d Pb The cl e bal n e cal lated f ur um nd le d may th b a id n tal Th fact th t l ad f m both feld par in the granite has an isot p c compo t on cl e t th t of n o d ary mod rn l ad f rthe ggests of external e t m ti n At y rat the lead th feld par i a m lou ltho gh it s n t cl r h the the ur f tam at n w s fr m hi th g a t r out de t S n only e g t ha be t d ed n th m n r there s gu nt th t th data r typ al of gran t s in g ne l Th result r p ent d t ll tr te the types f f rmati n wh h n be bt ned

th t p ese t-d y lead i the gr t c m posit is m lou h g a n g ti e m del age An m l u l d ha be n f u d n a h of two gran tes for whi h the i top c omp t of le d is kn n Th i d c tes th t gr n t s ha e h gh ur m l ad to than th t whi h e i t th sou e en me t wh h p d ed the le d n ga l as d p t m f ld p rs pl tted i F gs 1 a d 2. Gr tes a p ble f a m lo s lead if mech m exi t f r on tr t ng th le d nt e bod es p gm t tes

Lead isotopes and magmatic differentiation

Isot p c lead tud h be n u ed to d m tr t a g eti lation between ev al d ffe e t k typ n th So thern Cal f rni b thol th Gabb t n l t gr od o te a d gra te w e n lyzed Th Pb 06/Pb 0 t ar d f m 18 72 n the gabbr to 19 44 in the gr n t The ge f th bath l th c r t ly k wn t b 10 y r Tr at g h f the abr e ocks s l ed y t ms d l c l ting the top c c mpos t n f th lead 10⁹ y ag fr m the u i m l ad at t w f und th t ll of th Pb /Pb t s g w th l m t of err at 18 6 to 18 7 Th ium w s n t d t rm ed s th t mil r l l t o f r Pb 0 /Pb at o c ld t b mad The d t tro gly s ggest th t th qu ce of r k rigi nated fr m a large common re erv o r in which the isot pes f le d w re h mogene u ly d tributed [C R T]

B bl graphy F G Houterm ns Das Alter des Urans *Zeit Nat* 2 322 3 8 1947 J L. Kulp *Qua titat i Geochronometry* 1959 National Acad emy f Scien e *Cosmological nd Geol gical Im pl cat s of Isotop R ti l ariati ns* N clear Sci nce Ser R pt 3 1958 G R Tilt n et al I otopic c mp it n and di tribut on f lead u a nium nd th rium in Prec mb ian gr nite *G l Soc Am Bull* 66(9) 1131-1148 1955

Lead metallurgy

Ext acti n f l d from re and it s b eq ent pur f cati ge erally require pro sing thr ugh thre cla e f m t llu gical pe at n milling smelti g nd refini g Howev mi or to nage of cr d or by rea on of gr de other e o mic n d rat s or b th are hipped for direct m lt g

M ny moder le d ages w re kn wn t anc nt i il zat o a d ha e per i t d d wn th o gh the ce tur es Pr mary w rld c n mpti n exceed ng 2,000 000 t ns p year place le d fifth n a t n ge ba i am g the maj r i d trial m t l Se nty fi e pe e t f the w rld le d consump- tion s withi the ind t ial a e s of Europe and th Un ted St te Bec u e f its importance i the field f t an p rt t n (torage batt ies and t tr ethyll ad) chem cal nd ge eral p oce s ng (corro o re tant pip ng and heeti g bea i g a d x nd γ r y h eldi g) nd mmu icati ns (c ble sheath g) lead is la s fied as a trat g c mat r l by m t n ti ns *See* LEAD LEAD ALLOYS

Milling (ore dressing) In milli g lead miner l re phy lly freed f m ga gue nd other s- ated n tit e ts by dry rushi g a d wet gr d g Lib r ted le d m e l in the r s ltant l ry a e ep r t d by e th r g a ity cla fication r fl t ti n r a i ble mb n t n of both

Th p rt cular mill ng f l ti s a d flow arrang me t mpl yed r rel ted to th h r t r of o e f tre tment (e illu trati n) Compl x s lfide r s of i timate fi e grai ed mi eral zat on re us lly dry r hed in jaw and gyr t ry r h rs nd wet g nd n ball r rod mills pe ated in cl d cir it with cla s fi ati n equipment to a me h adequate f th l b r t of l ad ompo- ents fr m g g e and ther a ted min rals The le d m ne l c ntent of the re ulta t deslimed lurry i em ed by elect e flotati and the le d c e t ate p od ct s dew te ed by th ken ing and filtrat on

O c o ally m ll g p ctic s in the t atment of mple o e f e-g ed m n r liz tio such a occur in the Mi s ipp V ll y area m y leat g ty p at o with sele t flot t n empl yed nly f r re d l m ddl ng nd l m prod ct Here the hed e i p p ly ed l ed c cut w th ib at ng or tr mmel sc ee s d l fi rs. S p at n f th h gh d ty lead

one sample to another The Mi ssissippi Valley leads of Arkansas Mis ouri Illinois Iowa and Wi con sin have variable Pb^{2} /Pb ^{4} ratios which range from 18 5 to 23 Several examples are known of variable isotopic composition in different parts of the same mine Nonanomalous (ordinary) lead on the other hand does not display this variation giv ing almost the same i otopic composition through out a mine or even a geologic province Thus some sort of localized mixing is indicated to be the cause of anomalous lead

An occurrence of anomalous lead at Lake Atha baska Saskatchewan is well studied and will be used to illustrate a solution to the problem Urani nite in a pegmatite in the district is reliably dated *by concordant lead ages at 1 9 × 10 years Pitch blende of hydrothermal origin occurs widely and* isotopic ages all discordant have been determined for 28 of these A systematic study of the di cord ant pitchblende ages indicates that they could have been formed from a 1 9 × 10^{9} year old uraninite by dissolving parts of it 1 1 to 1 2 ×10 years ago and again about 0 2 × 10^{9} years ago transporting the uranium hydrothermally to new sites in veins and losing variable fractions of the accumulated radio-genic lead in the process Three kinds of lead are found in lead ores an ordinary lead and two kinds of anomalous lead Example of their isotopic com positions are given in Table 1

The ordinary galena may be used as a ba is to calculate the ratios of excess or radiogenic Pb^{20} and Pb^{206} the values of which appear in Table 1 It is also calculated that a uranium mineral formed 1 9 × 10^{9} years ago would contain radiogenic lead with a Pb /Pb ^{6} ratio of 0 17 1 2 × 10^{9} years ago and 0 12 2 × 10^{9} years ago Thus the urani *nite pitchblendes and lead ores tell a consistent* story pitchblendes were formed 1 2 × 10 and 2 × 10 years ago from 1 9 × 10^{9} year old ura nium minerals probably uraninite Varying propor tions of highly radiogenic lead separated from ura nium during the formation of the pitchblendes the freed radiogenic lead finding its way into lead ores which now contain anomalous lead The mixing of radiogenic lead with ordinary lead might be ex pected to have varied considerably on a local scale which fits observation

Other occurrences of *pitchblendes together with* lead ores having anomalous lead are the Colorado Plateaus and the Blind River district in Ontario north of Lake Huron These districts are not yet studied as completely as that at Lake Athaba k l ut a similar mechanism undoubtedly applies Th source of radiogenic lead for the anomalous Mi i ssippi Valley leads has not yet been identified N pitchblendes are observed and the Pb ^{08}/Pb^{2} ratios are high along with the Pb ^{6}/Pb ratio Perhaps another mechani m applies

Mention was made earlier of the fact that ign ous leads plotted below the average curve for g lenas in Fig 2 The mode of formation of anom lous leads cited above would tend to produce ju such a result if igneous leads represented unco taminated ordinary lead Highly radioactive mine als like uraninite contain lead with Pb /Pb ratios on the order of thousands and Pb^{207}/Pb *ratios on the order of hundred Mixing this le with ordinary lead produces a lead which will pl* above the curve for pure ordinary lead At lea part of the difference l etween the i otopic gro curves for lead in ores and in igneous rocks migl be the *result of this effect* It is more difficult recognize anomalous leads when they do not ha negative model age —they can then only be re ognized if regional studies have been made This not the case for many of the galenas hown Fig 2

Lead isotopes in a granite Another applicatio of i otopic lead data to geochemical problems illustrated by a study of the distribution of uraniur thorium and lead i otopes in minerals of a Pr cambrian granite from the Canadian Shield co *lected near Tory Hill Ontario Zircon containe* lead which was entirely radiogenic enabling th mineral to be dated accurately at 1 05 × 10^{9} year Perthite plagioclase and quartz contained lea which appeared to be entirely primary Determin *tion of the uranium lead and thorium lead ratios* i perthite indicated that the ratios were so low th the isotopic composition of the lead would not hav changed appreciably in the last 10 years if th mineral represented a closed system The other mi erals studied sphene apatite and magnetite a had mixtures of primary and radiogenic lead Th composite rock was analyzed for uranium thorium and lead concentration and lead isotopic compos tion From the age of the rock it is possible t make material balance calculations to study po *sible migration of lead uranium and thoriu* within the rock If each mineral has been closed system then the isotopic composition of lea calculated for the rock 1 05 × 10 years ago fro the present day uranium thorium and lead da should be the same as that found in the feldspar This comparison is shown in Table 2 It is obviou that some type of migration has occurred Th leads in the feldspars have model ages of about 10 years which suggests that they are contaminate with radiogenic lead and are anomalous A larg *crystal of perthite from a neighboring pegmati* was f und to contain ordinary lead with a mode age of about 10 years Several galenas with simila lead are also known from the district

Table 1 Isotopic composition of lead from the Athabaska dist ict

Type	Atom t			
	Pb / Pb	Pb^{2} / Pb^{20}	Pb^{20} / Pb	R d og n Pb / R d g c Pb^{20}
O d n cy	14 36	14 96	3‡ 49	
Anomalou	40 01	19 36	37 10	0 17
A om lo	43 5	18 7	35 7	0 12

from comm pra tice should be noted f exam ple, th pec al zed usage f a ti g he rth for the essentially one-step r a t red ct n of the ex cepti nally high grade M ssissipp Vall y mi e prod ti and the ubstit t on of an electric furna d conv rt rs fo the us l bla t furnace at the Bol de s op rati n Sweden

Le d m lt r charge p eparat n i clude im portant bl ding and co d t ing operat ns t prepare het roge eou crude ore a d fi e c cen tr te ece pts fo ec nom melting Coar e ore siliceo s d ba c fl xes a d c culat g lfur and l d d'lu ts are ru hed sufficie tly f int mate ssociat on with ch g fine Cha ge om po ents are p opo ti ed by riable- peed f der fr m mult ple b f bl nd g int a iform, m ture-aggl merated si ter plant feed flow by a ariety f arra g ments of p g m ll r tary drum mp t r rmi ng t ble f c lities

Str ght li e m ch e of the Dwight Lloyd type ar ed f r l ad-o e s nt r ng In the ual double-asting pr t ce fi st-o f ed at bo t 12% sulfu is roa ted t 4-5% then d harged cru hed and eturned ft the add t of a mall pe c t g of c ke, fo fin hing on second-o e units. I altern t ingle-pa s p a t ces all m chi es p odu e fi i hed nte w th ru hed fin ished p od t irc lated t ma ta the ulf co tent f aw feed at 5-7% Although mo t pre v ling p act e t lize d wn-d ft ir flow s ces f l p-d aft p a tice fa rable f h ndli g high l d chs g a d fo atta i g high sulfu di xide (SO) g c ntr tio s has ece tly been omm r ally dev loped

Bla t si te i g ac ompl hes both s lfur lim na ti a d n c pe t f o of ha ge p rt cles int a ll lar truct red te s table f blast furn ce edu tio Charg c mpon ts a e o d zed sulfu t d a SO a d an ut gen s te ng action p p g ted thro gh a lay ed and g i d charge bed by ndu ed i fl w S SINTERING

Blast f rn es e mm ly u ed f the sel tiv red ct of s nte t sl g d bull n com po nt Alth gh th y ary c d bl in d tailed des gn l d bla t f rnace a e ntı lly rectangul wat r j ket d struct 60-120 ft a a. d 18-22 ft high M lt pl r l t tuyeres ar prov ded l ng th l gitud n l d j t bo th cru ibl b Under n rm l run i g di ti n th furn shaft m ntai ed f ll by fre quent harg g l nte c ta ing bout 10% l ed k Cha g -c lumn bs d ti d th m al f m lten p od ts wl h h e be fused by c mb t on of ke with a bl w th gh tuy b l w A a gi en h rg laye bs de co ter to th upw d fl w of red c g ga ed c ti n and lu on e ac mpli hed w th the f rma tion f m lt n l d bull d zi c b ari g ir n lim b ate sl g In m p t c th b ll i t pped nti uou ly thr ugh a le d well nd th l g term tt tly th ugh a par t t p t th both d w o t u ly nd the lag and b lli n re then separ ted n he t d t

Comm rci l specifications of efined le d

	Corrod i g le d	Ch m l l d	A d coppe l d	Commo des l er ed l d
Si				
m %	0 0015	0 0 0	0 00	0 00
m %		0 00		
Coppe				
m %	0 0015	0 080	0 080	0 00 5
m %		0 040	0 040	
Comb ed Ag + C m %	0 00 5			
Comb ed A + Sb + S %	0 00	0 00	0 00	0 00
Zi m %	0 001	0 001	0 001	0 00
Iro m %	0 00	0 00	0 00	0 00
Bism th m %	0 050	0 00	0 0	0 150
Le d (by d f f ce) m %	99 94	99 90	99 90	99 85

n l f rehearth See PYROMETALLURGY NONFERROUS

Refining B th pyr met ll rgi l nd electro-lyt c p ocedures are u d for the refini g f lead bla t f rnac b lli n I ither e the bulk of th conta ed copper is first rem ed by s mple cool ng d o ng a d sk mmi g Just ab e the freez ng temperatur of the bull on most of the c pper pr ip tates and i sk mmed as matte- pei dr A final clean ng ag tat n with eleme tal s lfur followed by sk mm ng p ep res the b ll n f r uh eq e t per tio s

M st lead bla t furn ce bull n is suffici ntly low n b muth to perm t ec omi l pyrometallurgi al efi ng in kettle a d re e b ratory fu na es Tin ar ni and ant mo y ar sl gged at elevated tem pe tu e by s l ct e ox dati with a r F om the r ult t ft ed bulli n g ld a d s l er ar em ved by the P rke p o e s wh h util s thei select e affin ty fo zi c and perm ts u fac sk m m g of th I we den ity h gher melti g all y formed Res d l zi c in the b ll n s rem ed w th u ti (H rr s process) w th chl rin (Bet tert n proc s) o by acu m di tillation If th bull on at th s tage o ta n bi m th n e c of m ket ng specific ti n tre tm nt w th alc um m gnes um alloy (Kr ll Betterton pro e s) s nec s ry oth rwi aft r a fi al l ni g agitat on with c t c it s a t i t ma k t ble l to blo k 100-lb p g mall var able calki g sh pe

Whe the b m th c t nt s s ffic ently h gh, oppe dro ed bulli s c st i to anode and s ele trolyt cally r fi ed by the Bett p ocedu in wh ch p r l d starting cathodes nd n queou l ad fl l at ele tr lyt c ryi g r d amounts f le d nd f e fluo l c acid re us d P ci us metals nd th r mpuriti s c nta ned in the l ad ema n the n d a und l ed adh ent sl me h gh p ty le d s d p ted on c thod wh h at heduled i terv l r rem ed wa hed melted d ca t fo marketing (ee table)

[H E L]

B bl g phy W R Burr w Dev l pm t f a ti us pd ght s nte g p o es P c Aus

Lead smelt ng and ref ning

mineral component of the sized feed products is then effected by gravity in heavy medium cones jigs or shaking tables Heavy medium separation has also found limited application in the sink float upgrading prior to subsequent fine grinding and flotation of crushed low grade ores resultant from nonselective mining *See* ORE DRESSING

Smelting Smelting is employed almost exclusively for the actual extraction of metallic lead from its ores and milled concentrates In lead metallurgy the term smelting generally cover a sequence of three separate operations charge preparation blast sintering and bla t furnace re duction However certain cted deviations

( ) (b) ( ) (d) ( ) (f) (g) (h)

( ) (j) (k) (l) (m) ( )

Fig. 4 L f h p ( ) L (b) L n l t (c) Obl l t (d) Sp t l t ( ) Ov t (f) Ob t (g) Ell pt (h) Obl g ( ) D lt d (j) R n fo m (k) O bicul (l) P lt t (m) P rf l t ( ) Co te

The b e of th blade m y be cu eate wedge haped bl que th t d s f the ba e un qu l e rd te he rt haped ba e w th a c n pic u us n s uri ul t w th a small rl ke lobe n th d f pet le g tt te rrow haped w th p of b l l be t rned nward l tat hal berd h ped with ba al lobes t r ed utw d l p h n es il and partly n e t g the st m.

Leaf shapes A l af m y be l a l ng and n rr w th th ides p ll l or n rly (F g 4) l of t narr w b t t pe g fr m ba e to ard p l l l t b der t p taper ng t ard b se p tul t b o d a d bt e at apex t pe ng t ar ow l o t gg haped bro d est t w d b e b t re r of at br d t t d p ell pt c br d t at m ddl a d ta p ring l ghtly t b dly u d d b nd apex bl g mewhat e t ng la w th ne ly stra ght d and ro nded b nd pe delt d tri g l r f rm k dney haped b oade than long o bi ula i ul r or ne rly s p lt t shi d h ped usu lly i ula leaf w th p t l atta hed t n a th c nt of the low r fa perf l t h g the t m appar ntly p ng through t conn t n whi h th ba s f two p p te l a es m t h e f ed a o ind the st m

leaf l fl

( ) (b) (d) ( ) (f)

Fig 3 L af types ( ) S mpl (b) T f l te ( ) P l ly po d (d) Odd p t ly mp d (f) D mp u d

Leaf types A leaf is simple when it has l ut one bl de compound when the blade i divided i to two r more parate parts alled leaflets trif lio late if it ha thre l aflet (Fig 5) palmately c mpo d if leaflet or gin te fr m a comm n poi t at end of peti le pin ately comp u d if le fl ts are borne on the rachis (nti uat on of pet le) odd p nnate f su h a comp und leaf is te m nated b a leaflet e en pinnate with t ter minal leaflet de omp und (bip nate) if twice omp u d

Leaf venation Th arrangeme t f the ve n or a ular l ndle f a leaf i called venation (Fig 6) There ar three ba i types pa allel the main ein e te ding through mo t f the blade in a pa allel manner as in gr e lilies and most m cotyled n (*see* MONOCOTYLEDONEAE) net the m n ei s b anchi g f rming an irregula net w rk (p n tely if fe therl ke palmat ly if fan like) as i m t d c tyledo s di hot mou f rk d each e n di ding at intervals into small r et s of approximately equal size as n mo t ferns d in ginkg *See* FILICALES GINKGOALES

m d b

( ) b ( ) (d)

Fig 6 L f t ( ) P ll l (b) N t p t ( ) N t p lm t (d) D hot mo

Leaf arrangement (phyllotaxy) Le ve cc r o st m i definite fi ed rd r a d ng t spe s (F g 7) They s ally app i e f thre ways alt nate if o ly one le f occu t a node opp te f two l e app ar t a node n pp te ide nd whorled (e t ll te) if m r th tw app Alternat l a s a u ually ranged p r lly n the tem if they cur in but tw r w th y are 2 a k d if i fi e r ws 5 r k d

I a l te f fl we s a h flow r ar es nor m lly the a l (armp t) f leaf th leaf h eve s us lly mu h edu ed i s and i ll d a b ct Th b act s d to subtend the fl w r *S e* FLOWER (BOTANY)

Leaf surface Su fac s f l a e p vide m y cha ct u ed n dent fic t n A s rf ce is gla *b* f *it* mo th f e f m ha r gl c f d w th a wh t h w xy m t ial r bl m c b us fr gh o h r h t th t u h p be ce t g l t m f h ir ne of a y k d ppo ed t gl bro p *b rul nt* with ry fi e d w l k hai s t m nto w th matt d woolly h ll us w th l g ft shaggy h h sut d w th h t e e t tiff h s a d h p d d n w th b tly ha hly t ff hair

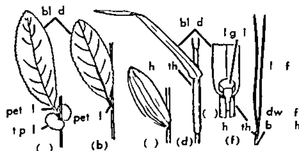
tralasian Inst Mining and Met 162–163 267–292 1951 T R A Davey Vacuum dezincing of de silverized lead bullion *AIME Trans* 197 991–997 1953 D Evers Debismuthizing by the Kroll Betterton process *Z Fr bergbau u Metallhut tenu* 2(5) 129–133 1949 H E Lee and D In gvoldstad The modernization of Bunker Hill pre sintering practices *AIME Trans* 206 1469–1473 1956

Leaf (botany)

Leaves are modified as aerial appendages which de velop from stems at nodes (stem joints) and usu ally have buds in their axils *See* Bud (botany) Stem (botany) In most plants leaves are flattened in form although they may be needlelike as in pine scalelike as in arbor vitae or nearly cylindri cal as in onion Leaves usually contain chlorophyll and are the principal organs in which the impor tant processes of photosynthesis and transpiration occur *See* Chlorophyll Photosynthesis Plant water relations of

Leaf parts A complete dicotyledon leaf (*see* Dicotyledoneae) consists of three parts the ex panded portion or blade the petiole which sup ports the blade and a pair of stipules mall ap pendages attached at the base of the petiole (Fig 1) Stipules may be green and bladelike as in pea coarse rigid spines a in black locust sheaths as in smartweed tendril like as in greenbrier or mere temporary hairs or bristles as in lespedeza Leaves that have a blade and petiole but no stipules are said to be exstipulate Some leaves have no ap parent petioles and are described as sessile The leaves of gra ses have neither petioles nor stipules the blades are attached to the tem by an encir cling sheath (*see* Grass crops) At the junction of the sheath and the blade is a collarlike structure called the ligule In pines needlelike leaves are borne in fascicles (clusters of 2–5 rarely 1) at the ends of short dwarf branches (*see* Pine)

Leaf margins The margin or edge of a leaf may be entire (without indentations or teeth) ser rate (with sharp teeth pointing forward) or serru late (finely serrate) dentate with coarse teeth pointing outward or denticulate (finely dentate) crenate or scalloped with broad rounded teeth un dulate with a wavy margin incised cut into irreg



Fg 1 L f parts (a) Compl te leaf (b) E st pulat leaf (c) Sess l leaf (d) Le f of g a s ( ) Det l f p t on of (d) (f) N edl l ke l a es of p e

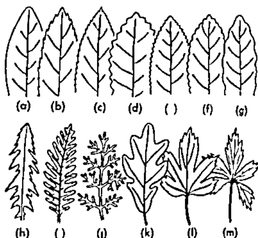
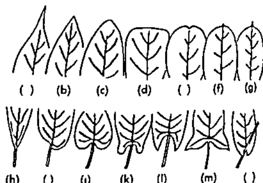


Fig 2 Leaf marg ns (a) Entire (b) Se rate (c) S ru late (d) Dentate ( ) D nt c l te (f) C enate (g) Un dulate (h) Inc ed ( ) P nnatif d (j) D ssected (k) Lobed (l) Cleft (m) Part d



F g 3 Leaf t ps and bas s (a) Ac m te (b) Ac te (c) Obt s (d) Tru cat (e) Em rg t (f) Muc at (g) C p date (h) C eate ( ) Obl q e (j) Co d te (k) Aur culate (l) S g ttate (m) H st te ( ) Cla p g

ular or jagged teeth or segments (if segments are narrow and pointed laciniate if directed back ward runcinate) pinnatifid deeply pinnately parted (featherlike) di ected cut into numerous lender irregularly branching di isions (Fig 2)

When the blade is deeply cut into fairly large portions these are called lobes The degree of uch lobing may be de ignated by the following terms lobed with sinuses usually not more than halfway from margin to midrib (mid ein) or ba e and with lobes and sinuses more or less rounded cleft when inci ions extend halfway or more from margin to midrib and especially when they are sharp parted cut so deeply that the sinu es extend almo t to the midrib or ba e divided cut entirely to the midrib which makes a leaf compound

Leaf tips and bases The tip of a leaf may be acuminate gradually tapering to a sharp point acute tapering more abruptly to a sharp point l tu e blunt or rounded tip truncate eeming to l e cut off square or nearly so emarginate decid edly n tched at tip but not lol ed mucronate abruptly tipped with a small hort point cu pi date end ng in a sharp rigid point (Fig 3)

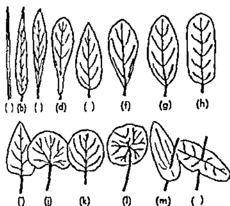


Fig 4 L f h p ( ) L (b) L ol t (c) Obl l t (d) Sp t l t ( ) O t (f) Ob vat (g) Ell pt (h) Obl g (i) D lt d (j) R f rm (k) O bicul (l) P lt t (m) P rf l t ( ) Co t

The b e f th bl de m y be cu eat wedg haped oblique, th tw d s of th b e n equ l c d t h art h ped b e with co pic i ulate with a m ll ea like l be n either de of p t le agittat rr w h p d w th pa r f ba al l bes turned i rd h t te hal be d sh ped th b l l b tur ed ot twa d l g h ile d p rtly i t g the tem

Leaf shapes A le f may be l n r lo nd arr with th des p all l r n rly o (F g 4) l lat n r w b t t pe g fr m ba e to ard pe bl n e l te br d t p taper g t d ba p tul t h o d a d bt at ap x t pe ing to b e t gg hap d b d ett d b se b te re of at br ade t t ard p x ell pt b dest t m ddl d t pe ing l ghtly t b dly r d d ba nd pex bl g, som what e ta g l r w th e ly straight des and nd d b e d p d lt d triangul r nif rm k dn y h p d br ad than l g bi lat ei l o n a ly p lt te sh ld h ped u lly a r l le f w th p ti le att hed at ne th nt f the l we f pe f l te h ing th t m appa tly p g thr gh t n t in whi h th b s f two p- po te l es em t h e fu ed ar u d the st m

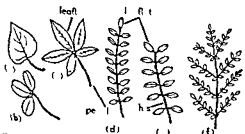
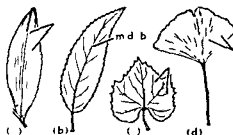


Fig 5 Leaf typ ( ) S mpl (b) T f l t ( ) P l- mat ly compo d (d) Odd p t ly mp d ( ) Eve p t l d (f) D mp d

Leaf types A leaf is s mple when it has b t one blade c mp nd when the blad is d ided int t o or more ep rate part called leaflet trifol o- late if it ha three leafl ts (Fig 5) palmately omp u d if leaflets or g nate fr m a comm n point at end f peti le pinn tely comp d if le flet are b rne on the rach (c nti uat n of pet ole) odd p nnate if u h a comp u d leaf is te m nated by a leaflet e en pi ate without t r m nal leaflet d c mpou d (l ip nnate) if twice mp u d

Leaf venation The arrangement of the vein or a cul r l undles of a le f i called e ati n (Fig 6) The e re three ba ic types par llel the ma n n ext nd ng thr ugh m t of the blade in a par ll l manner as in gra e l l e and mo t mon otyled n (s e MONOCOTYLEDONEAE) net the m in in br n hi g f rming an irregul r net work (p nn tely if f tl erlike p lmately if fan like) as i m t d cotyled s dichot mou f rked ch ve n di ding at i tervals int sm ller em of appr ximately eq al si e s in m st ferns and i g nkg Se FILICALES GINKGOALES



Fg 6 L f t ( ) P ll l (b) N t p t ( ) N t p lm t (d) D h t m

Leaf arrangement (phyllotaxy) Lea s oc u n a t m n a d fi t fi ed rde acc rd ng t peci (F g 7) They us ally pp e f thr w ys lt n t f o ly n l af oc ur at a d opp ite f two lea es appear t a nod opp te ide nd wh led (ert c ll te) if m re th n tw appe Alte nat le e are u ally a ged p r lly n the stem if they oc ur n but two ws th y a e 2 ked if n fi e r w 5 nk d

In a l st r of fl w ach fl we a ses n r m lly i th a il (armp t) of a l f th s leaf h w e s u lly mu h ed c d in i nd alled br ct The b ct i s d t subt d th fl we S FLOWER (BOTANY)

Leaf surface S fa es of l p de m ny char t d n de t fi at A s fa e i gla b f t mo th f e from h glau s f d with a wh t h w xy mat al o blo m c b s if r gh ha h to th t h pube ce t g l te m f hair of any k d a pp d t glab u pube ul nt w th y fi d w l ke h t m nt e with m tted woolly h llou w th l ng oft, h ggy h rs h te o ed with h rt e t t ff ha a d h p d d with b tly h r hly t ff ha

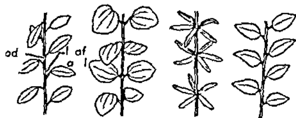


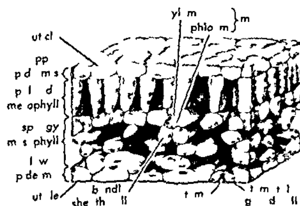
Fig 7 Leaf arrangement (l to r) alternate oppos te whorled alternate 2 ranked

Leaf texture The texture may be described as succulent when fle hy and juicy hyaline if thin and almost wholly transparent chartaceou pa pery opaque but thin scarious thin and dry ap pearing hriveled and coriaceous tough thickish and leathery

Leaf duration Leaves may be fugacious falling nearly as soon as formed deciduous falling at the end of the growing season (*see* DECIDUOUS PLANTS) marcescent withering at the end of the growing season but not falling until toward pring or persistent remaining on the stem for more than one ea on the plant thus being evergreen *See* EVERGREEN PLANTS PLANT ORGANS PLANT PHYS IOLOGY PLANT TAXONOMY [N A]

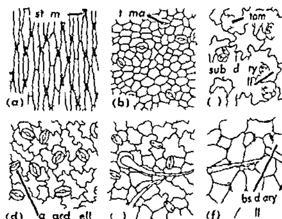
LEAF ANATOMY

In a true leaf the veins are continuous with one or more vascular strands of the stele the primary vascular cylinder of the stem (*see* STELE VASCU LAR BUNDLES) The trands that connect the leaf with the va cular system of the stem are the leaf traces A part of such a leaf trace passe through the outer stem tissue or cortex (*see* CORTEX PLANT) Above the point of divergence of the leaf trace from the stele an interruption of the vascu lar tissue occurs and this parenchyma filled area i the leaf gap (*see* PARENCHYMA) Although there are *flattened leaflike tructures among the lower* plants such as algae liverwort and mo ses these are not true leaves because they lack a v ell defined vascular system (*see* ALGAE HEPATICAE MUSCI) Some of the primitive vascular plants have micro phylls (small leaflike organs) but these have a sin gle unbranched leaf trace and there is no leaf gap in the stele



F g 8 Th ee-d m ns onal d ag am of a b fac al m o m ph c leaf

Internal structure in relation to function Th foliage leaf represents the chief photosynthet component of most va cular land plants (Fig 8 Although leaves vary greatly in size shap ar complexity they consist of the same three ti u as does the stem dermal or surface layer vascul including the xylem and phloem or conductive ti *sues and the ground tissues parenchyma* an sclerenchyma (*see* EPIDERMIS PLANT PHLOEM SCLERENCHYMA XYLEM) In the leaf however th *arrangement and modifications of the e tissues ha* obviously evolved along lines favorable for phot synthesis within various habitats and climates (*se* EVOLUTION ORGANIC) The ground tis ue or me phyll of the leaf is primarily chlorenchyma th is tissue with cells containing chloropla ts (*se* CELL PLASTIDS) With a maze of intercellul spaces in the chlorenchyma each cell is expo ed t an int rnal moist atmosphere The sheetlike di tr bution of the chlorenchyma in the blade expos each individual cell to light The vascular ti ue an intricately branched network of veins en bedded in a midplane within the chlorenchym



F g 9 Su fac ew of the lowe ep derm s of lea how ng d str but o and po t on of stomata nd rel tive s e a d shap of s bsid ary c ll The dotted l ne show th outl ne of guard c lls or subs d ary c lls th a e b cu ed f om su face w by ov lappi g cell (a) Ir s (b) Vit s (grape) (c) S dum (d) Cap cum (ec p pp r) (e) Lycopersico (tomato) (f) O alis Note that the dotted l n s ind cate that th stomat are su ke n l and O al s a s d n S d m Caps c m and Ly opers nd flu h n V t (Fr m K E au Plant A atomy W ley 1953)

Every cell of the me ophyll therefore is relatively close to ma s movement of water and solutes through the xylem and phloem of the veins—wa ter and mineral ions m e chiefly through the xy lem di sol ed foods chiefly through the phloem *See* PLANT MINERAL NUTRITION OF PLANT TRANS LOCATION (ORGANIC SOLUTES) The nongreen com pa t epidermis is similar to the epiderm of stems and ther exposed plant organs (Fig 9) The stom atal guard cell al ne among the epidermal cells c ntain chloropla t and the stomata con titute openings in the otherwise continuous epidermis the





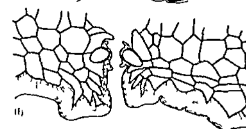
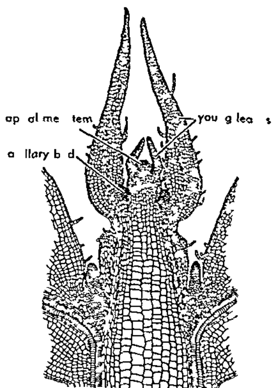



Fig 10 Tra se t f t m t th l w pd rm f l av h w g d g f d d unk p rt f th g d ll l t t b- sd ry p d l ll N t th t th t l f m p rusio l dg t th t m t l p g ( ) P (pe h) (b) P st (p rs p) ( ) S l m (potato) (d) H d (E gl h vy) ( ) M (b) (f) E y (Ad pt d f m K E Pl t A t my W ley 1953)

ll of wh h e d by w y f tty c t l (F g 10) Th the p d rm t ansl e t t p oofed b t part lly p f ated g th gh h h l ght p t t but th gh wh h th d ll n f w t p r d ga l m ted These g se p p c p lly th gh th to-

mata The open ng and cl sing f stomata within the epidermis f many lea es re ult e sentially from light and temperat re en t ity Thu dur i g p ri d f rapid phot ynthe when diffu i n pre re grad ents f ga e (between the internal spaces a d th extern l atm phere) are teep the t mata e op Alth ugh water l i h gh dur ing these p riod water con erved at other times whe the st mata are cl ed The intercell lar sp ce f th me phyll are lined with a th n fatty film mil r to the cut le i comp iti Th film n d bt i l bit ap r tion to me extent from the mes phyll ell t the i tern l spaces

In well differ tiat d bro d le e the chloren hyma con i t of two c ntr ti g ti ue y tems pal de d pongy me phyll P lisade ells are typically c lum r i hape l ely p ced and ori ted parallel with e a ther but with their l g t d meter at right angles t the u f ce of the blad Sp gy me phyll cells n the contrary e a t l sh ped and are o iented w th the l ng t d m ter chi fly in the p rad rmal pl ne (the pl ne f the bl de p rallel with the ep dermal l y r bl d urf ce) The great r p rt of ph to- y the o ur with n the pal ade ells wh r th hl ropla t are m st numer u T a fer f w t r and lute fr m li g cell t l i g cell nd b twee v ns o ur chi fly th o gh th



Fg 11 L g t d l ct th gh h t t p (t m l b d) h w g t g th d l pm t f F l g l f m th p l m t m (F m E N T H C S mp d L H T ff y T ib k f B t y d H p 1953)

spongy mesophyll and dermal tissues becau e these are the tissues having consistent lateral contiguity There is only limited lateral contiguity among the palisade cells

Among leaves in which guttation (s cretion of water from the tip and margins of leaves) i known to take place pecialized tissues called hy dathodes occur near the vein endings in the blade tips and margin Mo t leaf movements are caused by irregular growth rates (see PLANT GROWTH) but certain reversible movements are caused by changes in water content of cells within pecialized structures such as the pulvinus (a swelling at the base of the petiole) Ergastic substances (waste products and crystals of mineral elements) accu mulate in various living cells of foliage leaves With leaf abscission (fall) these wa te materials are eliminated from the living plant

Leaf development Each foliage leaf whether simple or compound arises as a leaf primordium (a protrusion compo ed of relatively superficial cells) at the apical meristem or region of cell divi sion at the shoot tip (see MERISTEM APICAL) As the leaf primordium elongates and thickens by nu merous cell divisions a primordial axis form which later differentiates in part as midrib and petiole (see MITOSIS) On either side of the axi marginal meristems containing marginal and sub marginal initials give rise to a number of cell lay ers from which the blade tissues differentiate

In woody plants tiny folded leaves with recog nizable shapes can be distinguished in winter bud These young undifferentiated leaves develo, u buds during the growing sea on preceding the win ter Thu in the spring as the buds open and the bud axis elongates forming the new twig the tiny leaves unfold and expand to their mature size within a few days Although during this surge o spring growth a limited amount of cell divi ion oc curs the major activity is concerned with cell en largement and differentiation In ome woody plants additional leaves arise and mature during the same growing eason Foliage leaves con mainly of primary tissues (tis ues that arise from the apical meristem or the embryonic t m tip) and except for some ferns and a few seed plants

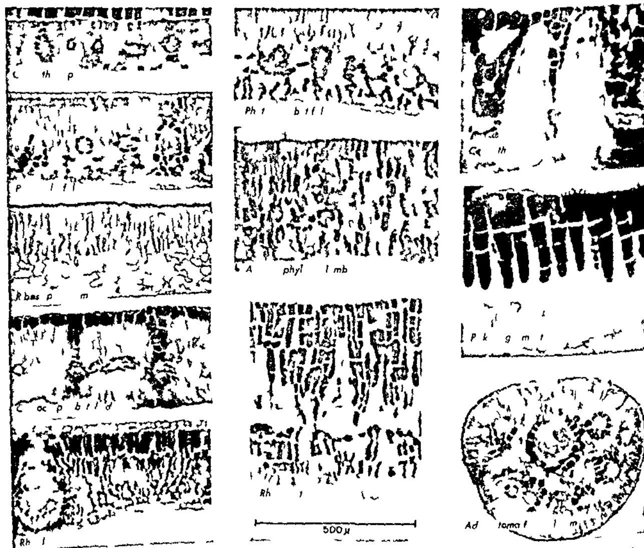


Fig 12 Trans erse sect ons of th xe omo phic leaf blades of ele en spec s of e e gr en chapar al shrubs f om the Santa Monica coastal mount ra ge of Cal fo n a Although the mesophyll of most of these lea es I p edominantly p l sade the st uct l b f c al fo ele e and cent c f on Note the l t vely th n epide mal lay s

ha e determ ate growth (as cont asted with co tinued gro th of a tem) Le es of ome ocotyled ns complete terminal g owth and e n in w dth but they c t nue to grow for a d rable time f m m r tematic cell in the b se (F g 11)

f absc s n occ s t th e d f a single wing easo n decidu s woody pla ts Am g rgree spec es howeve the le s pers t gh se al growing as s Leaf ab cis ion urs ithin a defi te zo e near the ba e of the le. Aft o somet m d i g ab ci n a f sube in and a gumlike sub tance is ecreted the l g ell forming leaf c o cicatrice A corky ti s e pe iderm then f rm by l d n der the at e (se PERIDER 1) th n the l f s are b dle scar wh h h w ere the sc l r b dles ab c s d Ab ci sion the t p les d h act lly o c ery early th growi g se on Leaf ars bundle s d st pule ars are di t gu hing f at res of m c mp rt nce

Factors that influence structure B th he ed ty d en ment ar respon ble for th great ar m l f tru t e Alth gh he d ty ac o ts a gr t array of forms th pla t u ually h e m of th tru t ral feat es s o at d with th h t t (e vi o m nt) Striki g s m l ities e bserved am g un el ted but ec l gically c rgent pl t f rms (sp th t ha e e l ed sim arit es f f rm nd beha o with a g en h b t) Th r f ot all t tural ch cteri t effect phyl g tic el ti hip that s, relat ups th t i d t m l r evol tio ry h t ry Alth ugh e l g c l eq len am ng u ted spec s n t f lly u de stood some g e l f rms are c mm ly ci ted w th erta ell-d fi d e vi m nts h b t t For e am le, m i t bo l fo e ts e dom ted by tre th eedl l k eve g een le e t mpe ate r ny egi s, by trees with br d d ciduo l es Med terran lim tes r domi ted by hrub and mall trees th h d br d eedl l k l e Perhaps th l g al equ le ts m t d fficult t d t d a th de ert h ubs Some f th hrubs h m ll u fy h ry ly de d s le es a f w ha m ll rn h d eve gr lea es and t'll othe s s c ul nt a d p ct c lly l g

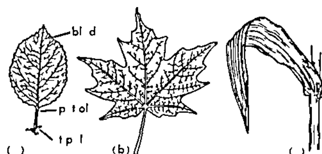
X phytes and hyd phyt s r th t rm used for pla t that n rm lly gr w i dry (x ri) a d moi t h b t ts, re pe t ely Mo t pl t th t grow in tempe t cl mat s a e m sophyt s f e mpl the comm n cr p pl nt s d d t be m hytes h h a i termed t betw n th o- phytes d hyd phyte th m t e req i ment Th h m y t m al st d f pl nt gr g in ext me and t mp r te hab t ts cert n truct l fe t es h e bec me k wn e m r phic, mesom ph c, r hyd m phi S e ome f th t t al f t q t t t u h n p g d th k e f c t cl o s de- tr es f m phy r hyd m phy n b b- served in otherwi e me m rph c pl nts F r e ample am g le e on typically mes m rphic pla ts th e at the higher le els f in erti n on the pla t u ally show ome xeromorphic tend encies as compared with lea es at lower le el and the leaves that h e devel ped in full sunlight are more xeromorphic tha the n that devel p in th h de Among lea e of m som rphic plants grow i g in dry and moi t hab tat the leav f pl nt from the d ier habitat h w a tendency tow rd xeromorphy Xe m rphic fe t es are n t al ays e ly interpreted S me a pects of xeromorphy are ass c t d with higher r ther than l wer rate f transpirat and xerom rphy is characteri t c of pl nts grow g in wet peaty il as w ll as i dry hab tat (Fig 12)

Dermal tissues Ep dermal cells are typically tabular in h pe but the surface and inner wall may be flat rou ded or p pillo e (with c nical p tuberance) and the ant cl l wall (wall at right gles to the surfa) are flat r und late (wavy) The surfac hapes f epidermal ells re polyg l amebo d or nuo Fp derm l c ll o the low surface re us lly smaller and more sinuo th n are the pper ep dermal cells Cell of h de lea es and hydr m phi leave are m e ous th n th f s lea es and xer morphi lea es

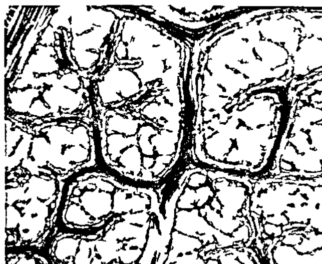
The upp or l wer ep derm s m y cons t f m ltiple l vers It is t rmed multiple ep dermi f all f ts cell arise f m the pr t derm (the sur face me istem fr m wh ch the epid rmi is de- ri ed) If the s bderm l cell ar de i ed fr m a int or m ist m the ubderm l t su is termed hypodermis S bdermal ell re usually fewer i mb d l ge n v lum than a e the accom p ny g ep dermal cell a d th y t nd t be l s riable i hap (u lly isodiametri o elon gated polyhedr) The mult ple epidermis a d hyp dermi are h ra ter tic f tr p cal evergreen lea es Dermal t sues compo e 20-30% f the to- tal bl d lum in mes m ph c lea s h t om xer m rph c le s h v ry hallow p de mal laye

Th ut le th t e s the ut r su face of th ep d rm i comp d f aryi g m t of utin d p t n (ee PECTIN) The outer w ll re not only c t cula i d (e ed by l y f cut n) but in dd t n they are ut ized (mp egn t d with cut) R d l piderm l w ll r l o f e- q e tly tin d Hea ly t n ed epidermal c ll t nd t be ather un form nd d metr c in hap

Th st mat m y be flu h with dj ce t ep d r m l ll th y may b ra ed r ke Stom t re l fi d h efly p n th b s of h pe and e t t n f s b di ry c ll (cell djac nt t th gu d ell) In d s t l blad s f meso- m rph lea es d t p c l ev rgr en lea e th t m t c fi ed p i cip lly t the l w epi d m l fl t g le es f w t r pl nts well de- el p d t m ta f u d ly with the upp r p d rm l x mo ph i l t r l l a es d y



F g 13 S mple lea es illust at g the arrangem t of prominent veins Blades (a) and (b) ha e the netted ve n a rangeme t (a) Pinnately veined leaf of apple (b) Palmately veined leaf of sugar maple (c) Parallel enat on of a co n leaf (*Fr m C L Wilson and W E L m s Bota y ed Holt 1958*)



F g 14 Photom crograph of the t cate netwo k of m or ve ns and assoc ated spongy m sophyll of *F cus elast ca* The t s s ct o was cut from a m dpla e of the blad p all l w th th su face of th l f

lindrical leaves the tomata are distributed over the entire surface Stomatal frequencies have been reported for a number of species and they range from 14 to 1540 per mm

An epidermal appendage (trichome or hairline structure) may be a simple outgrowth of an epi dermal cell or a unicellular or multicellular struc ture The separate cells may be relatively undif ferentiated or secretory (glandular) in nature (*see* SECRETORY STRUCTURES PLANT) Idioblasts (cells markedly different in shape or funct on from other cells within the same tissue) and cells with crys tals and other inclusions as well as trichomes are constant feature of certain pecies

Mesophyll In bifacial leaves (th se with dis similar tissues above and below) the chlorenchyma consists of one or more layers of pali ade cells near the upper (adaxial) surface of the l lade and one or more layers of spongy mesophyll cells in the lower (abaxial) portion There i relatively lit tle lateral conti uity among the pali ade cells al though ome of the cells are tangent along portions of their lengtl Pali ade cells subtend epidermal or hypodermal cells and are contiguous with the spongy mesophyll cells below In mo t me omor phic leaves the spongy mesophyll include large in tercellular space and its cells are oriented chiefly within the paradermal (horizontal) plane of the blade If the cells are branched one or more arms are extended within the paradermal plane In the midplane of the blade which includes the intri cate system of minor veins the spongy mesophyll is in the form of continuous nets of living cell closely integrated with the mall vein The inter cellular space system in the entire me ophyll ti sue of measured leaves accounts for 35-71% of the entire blade volume Although the greater vol umes of space are within the pongy me ophyll larger internal surfaces (cell wall surface lining the intercellular spaces) are expo ed within the pali ade mesophyll Among measured leaves the internal expo ed surface is 46-31 time as great as the external blade surface of the ame leaves In a few species the pali ade cells are H shaped or U shaped in other species the columnar cells are laterally contiguous by adjoining protuber ance The numl er of layers of pali ade may vary in leaves on the ame plant In i olateral blades (blades with imilar ti ues on both id s) the me ophyll consi ts entirely of pali adelike cell or palisade cells occur in both adaxial and abaxial portions on either side of a midregion of pongy me ophyll In the all pali ade leaf the cells in the midregion of the blade have some lateral contigu ity In ome foliage leave the pali ade and spongy mesophyll are not highly contra ting tissue The degree of contrast between the clo ely paced ver tically oriented pali ade cells and the more d f fusely spaced laterally oriented spongy me ophyll cells varies with the species as well as the environ ment

Vascular system The two main patterns of vena tion (arrangement of the prominent veins) in broad foliage leaves are netted and parallel (Fig 13) Most dicotyledon have netted veins and the most prominent eins are arranged pinnately (one midvein with secondary veins diverging from it) or palmately (several large eins preading out from the ba e of the blade) Among the larger eins an intricate network of minor veins is well di tributed within a median plane of tl e me ophyll (Fig 14) Most monocotyledon have parallel veins (main veins arranged longitudinally within a linear blade) interconnected by smaller veins

The primary and secondary eins along with as ociated mesophyll tissues form prominent ridges (vein ribs) on the abaxial side of many foliage lea es The midrib reg on of such leave is imilar in structure to the petiole it con i ts primarily of one or more vascular bundle of xylem and phloem (the xylem n the adaxial side) and upporti e tis ue Xylem or phloem fil er or both may be pre ent and s me of the ground tis ue n either ide of the ein proper may be in the form of c llenchyma a ti sue consi ting of el ngate cell with unevenly thickened walls (*se* COLLENCHYMA) The paren chyma a sociated with the ma or ein has rela

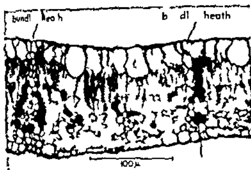


Fig 15 T nse s ct th gh th b f l fol ge leaf f F y mo howing w th b ndl sheath t ns.

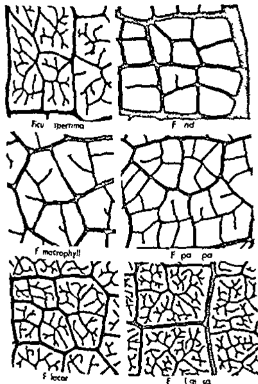


Fig 16 Diag m f m p tt rn f specie f F Th t ppled th e w th b dl sh ath xt n Th s p t d by l d broad r mb dd d th me phyll d l k b ndl shea h e t

tir ly f w hl pl ts The epiderm l ell n h thi g th m jor e e f ; ntly elo g t th th r ax

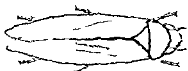
Th m n s that a mbedded i the me o-phyll con t f xyl m nd phl m l m nts cl ly surr ded by b dle h tl h th of thin a led p enchyma cell (F g 15) There n pport tis bo t th m i Som et end g en t f gle t h d (yl m lement) phl m nd a b dl h th B dl h th ry i mpl x ty a d may h ly few

no chl ropla ts Howev r i a few xe om rphs the bundle heath the principal chl r phyll bear i g t ue In ma y d tyled ns l ndle h atl te on (panels of p enchyma cells) e te d fr m the b indle sheath to ne r both ep d m l layer S ce th l indle h ath ext ns u ually ha e l ttl chl rophyll they appear like p rtiti n betwe n block of ph t ynthetı m sophyll within the blade B dl heath ten i ns e of frequ nt o r e ce i d cidu u f l age l a e The min r e amify thr ugh the m dplane of the me- phyll arıou mple p ttern (Fig 16) In the p ra de mal pla e inter n ecting minor ein may f rm l ed n t or they may be dendriform (ar anged n intri at bra ch ng y tem) with nu me u e n nding [S P]

B bl g aphy *Se* PLANT ANATOMY

Leaf hopper

Any of umer u spec es f the insect f mily Cicad ll dae o der H moptera This i e y la ge family and incl des an uncert in numb l spe es f m ll l nder i ect f eq ently trik ngly ma ked in brill nt c l rs They re dist g hed from m lar f m l l y the d i l le r w f spines the h d t l a their w ng meet in a deeply n erted V a d t nd b yo d th tip of the bdo-r e the eyes ar ually large



R l f hopp *Emp o* l gth t ¼ n (F m *E L P lm F ldb k f N t l H st ry McG w H ll* 1949)

Alth gh each pe es i ge er lly r t icted n its h b t t and the pl nt n whi h t f eds, ther a e leafh ppers i irtually e ery s t at whe pl nt g ow

S al a e f e on m c imp rtan feed ng ar ty f fi ld nd gard rops M ny k w s h p hoot l e n cotto *S* HOMOPTERA [J D B]

Learning theories

A fi ld f psy h logy embr ci g hab ts kill mem es a d p bl m sol ng incl d g the qu t on r te t nd t lizat o Theo ies f learn g ha b e e l ed by psychol g t w k g *th* timul e po c d t ed r flex, *o* ept d th g it r awar es n ept *Se* MEMORY PROBLEM SOLVI G (PSYCHOLOGY) SENSORY LEAR ING VERBAL LEARNING

Stimulus response concept Cond t n ng e p me t h y lded rt n l wful r l t h p u h a f bl *tim* *t rval* betwee t m l effe ts of ate l p nt t p n qu t p ta e us ry f *esp* t ngth foll w g edu ti th o gh ext n t n p oced e and so

on It is assumed that these relationships can serve as the basis for predicting more complex habit phenomena such as those involved in learning a language or operating a typewriter Application of conditioning principles is not solely by analogy *but the effort is made to predict effects that* super ficially are unlike the relationships used in predic tion For example the fact that items in the middle of a li t are more difficult to memorize than items *at the beginning or the end is not reflected in sim* ple conditioned reflex experiments Yet it is pos sible to use relationships from these experiments to predict this fact C I Hull was a leading theo rist *in this field and his proposals have been ex* tended and modified by N E Miller and K W Spence

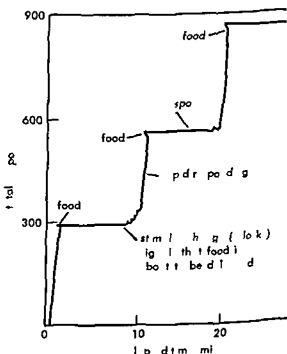
Hull recommended the hypothetico deductive method That is he preferred to set up a mall set of postulates which are relation hips from sim ple conditioning experiments usually empirically established From these he proceeded to deduce more complex phenomena as theorems These theorems if confirmed by experiments tend to con firm the postulates In order to simplify the total number of postulates he departed omewhat from purely empirical relationships in order to infer intervening variables as simplifying constructs These intervening variables given such names as drive or habit strength lie between the ob served timulus or input variables and the meas ured respon e or output variables Hull s most ba ic formula I ecame

$$_{S}E_{R} = H_{R} \times D$$

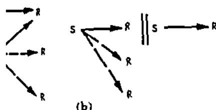
in which each of the terms is an intervening vari able Thus $_{S}E_{R}$ is the inferred reaction potential which if above thre hold leads to the measurable overt response R to the stimulus S This reaction potential is some multiplicative function of habit strength ($_{S}H_{R}$) acquired as a result of repeatedly rewarded experiences and the motivational con ditions or drive (D) acti e at the time Thus habit is activated into behavior only when the dri e conditions are adequate Habit strength depends upon rewarding circum tances known as rein forcements The complete formula for response evocation includes a number of factors in addi tion to habit and drive for example stimulus in tensity and the amount of reward used in prior reinforcement

B F Skinner also bases his interpretations on the data *from conditioning* experiments and ac cepts reinforcement as the basic operation for re sponse strengthening He takes a more positi istic approach than Hull but disclaims the notion of *intervening* variables and refuses to use the hypo thetico deductive method He has I een successful in demon trating a great deal of lawfulness in learned b havior using a variety of schedules of intermittent reinforcement that is reward on only a predetermined fraction of the trials *In Skinner* spot pecking experiments with pigeons the bird receives food reinforcement following pecking at a target but the food is delivered only once every 10 minutes The target at which the pigeon peck changes slowly so that it serves as a kind of clock The pigeon begins to respond 7–8 minutes follow ing prior reinforcement and is re ponding more *than 10* times per econd by the time food reinforce ment is delivered (Fig 1) While his ba ic work has been on lever pressing by rats and pot pecking by pigeons Skinner has had some succe s in ap *plying his analysis al o to* verbal behavior chool room learning and the behavior of psychotic pa tients

There is also a nonreinforcement variety of learn *ing theory according to which the basic relation* ship for habit formation is merely the contiguous presence of a stimulus with a response (Fig 2) A sophisticated theory derived from the contiguity *principle* has been *propo ed* by F R Guthrie and given mathematical expression by W K E tes and C J Burke The mathematical model is ba ed on the assumption that the learner is ensitive to ome fraction of the total stimulus complex available to him and that this fraction becomes attached or conditioned to the respon e that occurs Hence as a response is repeated an increasing fraction of the possible stimulus components will have been con ditioned to it so that the response becomes in creasingly probable on later trials The model de scribing this increasing probability makes u e of the mathematics of et theory and is known as a stochastic model (*see* STOCHASTIC PROCESS) The model and its parameters are logically specified and the parameters are then empirically deri ed by curve fitting (*see* BIOMETRICS BIOPHYSICS MATHE MATICAL) *Considerable success has been* achieved especially with relatively simple probability learn



Fg 1 Cont l of po by re nf ceme t (Adapt d f m C B Ferst r and B F Sk e Sched les of Re fo c me t Appleto Ce tu y-C (s 1958)



N f m t d f m t S-R th o- IN e f rc t S-R th ry C dt ed t m ,) ke R th th R R b c th r s (S) c R t c th p f S Is called ng ty th ry b c th c f S d R ll th t d d t p od soc h b tw th m (b) R f m t S-R C dt d t m t (S) k R t h gh b1ty th R d R (th p ts ory) bec se R h b f ll w d (w d d f d) by S_0 t d g t R_0 g l t m l s espo se

ss t gue g wh h of tw l ghts w ll c me n t the pe imenter u es r d m der but e li ht elat ely mo e f eq ent tha the r

them ti l model a e ot lim ted t th c ity t pret ti in fact by p ov di g tra t t qu t s th y m y e l that some of d t n t on betw n re f c me t a d ntu ırt ıp et t ns e c ent fic lly un mpo ta t r a ties of model h bee p ided by I.B h d F M t ll r F R tle d oth ll f the wpoi t thu f m t o d l fy s b t o a so at n th t and e ommo ly ped t geth s tim l s- e p s S-R th s Some S-R psy h l g t ha e dev ted m e ntion t e mple h ma l a g in r te t l m m zati n per ept l m t k ll se exp rime t re e l l wf l p pert at th n lev l of compl ty u h as er l po ti n rts, short-c iti g o pl ce k pp g te de s int li t nd int l t effect Th wh ro eti al wr t ng in l de tatements d t g m th lev l of c mpl ity e c mm nly known f t al t f wh m A L Irı A W M l n, s d B J U d rwood c nt mp ry ep e- tat

Cognitive concept S t ppo t o to the S-R eori ts e a umbe f p ychol gi t wh em h ze th mp rt n f g t f t s n le rn g th t is pe ept l d ti l p o e tinct f m rim t h b ts Th y s le ig n t m ly ha of d t oned fle ut a a gn f ll w g p oce wh ch th l r e om h w k w what l d to wh t d c n nod fy h beh r d ngly Wh t i le rned lding f a m em t p tte n fi ed by h b t Al ho gh th p geon e p e n F g l re sed t ll t t f m nt theory th y ls p e t n ad pt t t the p tt ed at f th tim

l ti n in time the u of the cl k by the pigeon is here t with cog tive theory Cogniti e the ri t tend t u e ch oncepts a ins gl t or ex pectat n when they de cribe the c ntrol of be ha i r The nam a ated witl the c gniti e po t n i clude tl e Ce t lt p ychol gi t espe c ally W lfg ng K hl r and Kurt Lew and ome ne beha iori t f r i tance Edward C T lman and Karl S La hley

Wl le f a t me the inter t in l eha i ral law o had wed interest in neur phy iol gical co relate of learn ng si e 1950 there h been re- newed nter t n br n pr c e underlying le rn ng Thu far the pe if c eur l hanges related to l rni g a e u known *Se* P YCHOLOGY PHYSIO LOGICAL AND EXPERIMENTAL [E R H]

Bibl ogr phy E R Hilgard *The t of L n g* 2d ed 19 6 J A McGeoch nd A L Ir o *The Psych logy f H ma L rn g* 2d ed 19 2 R S W d rth and H Schl be g *Exp r m t l Psych logy* r ed 19 4

Least action principle of

L ke Hamilt n pri pl the pr nc ple of le t a t n s a ar at n l st tem t that f rm a ba i f om wh ch th eq at n of m ti n f a la cal dy m al ystem m y be dedu ed (*s e* HAMIL TON S PRI CIPLE) Co ider a mechani al ystem d c bed by c ordi te q q_j d th ir an ni lly j gate mome ta p_j p_j (*s e* HAMILTO S EQUATIO S OF MOTION) The ct on S a o ated w th a egm nt of the traje tory of the y tem is defi ed by

$$S = \int \sum p \; dq_j \tag{1}$$

wh e the teg al i eval ated l ng the g en egme t of th tr j ct ry The a t o t of i t r t nly wh the t t l e gy E on rved The pri c ple of le t act o tat that th t j ctory f th sy tem i that path whi h m ke the al e of S tat on ry rel t t ea by p ths b tw n the me c nfig rati n d f wh ch the e gy h s the m c tant alu Th p ple i mi n m d as ly the t t ary p ope ty i equ red It i a m n mum p ciple f ffi e tly sh rt but fi ite egme t f the traject ry (e MI IMAL PRI CIPLES)

Let

$$S + \Delta S = \int \sum (p + \delta p)\, d(q + \delta q) \tag{2}$$

wher $p_j + \delta p_j$ a o ally c jug te t $q_j + \delta q_j$ Negle ti g e d rde terms

$$\Delta S = \int \sum (p \; d\,\delta q + \delta p \; dq)$$
$$= \int \sum (\delta p \; dq - \delta q \; dp) \tag{3}$$

wh e n i tegr t n by part has b mad the i teg at d p ts n h g

The i h g f ΔS r q th nt gr d to b pe f t d ff t l of a q ant ty who d i t h Th coeffic e ts f th r at s

$\delta q_j \; \delta p_j$ need not vanish separately because the variations are not independent the varied qs and ps necessarily being canonically conjugate

$$\sum_j (\delta p_j \, dq_j - \delta q_j \, dp_j) = dU(q\, p) \qquad (4)$$

where $$\delta p_j = \frac{\partial U}{\partial q_j} \qquad \delta q_j = -\frac{\partial U}{\partial p_j} \qquad (5)$$

Writing $U = -H \, \delta t$ leads to Hamilton s equations of motion

$$\dot{p}_j = -\frac{\partial H}{\partial q_j} \qquad \dot{q} = \frac{\partial H}{\partial p_j} \qquad (6)$$

The quantity $H(q\, p)$ known as the Hamiltonian function does not contain the time explicitly because $U(q\, p)$ cannot be a function of the time as the end times are not fixed and in general will vary as the path is varied Thus the principle is useful only for conservative systems where H is constant

If $H(q\, p)$ consists of a part H_2 quadratic in the momenta and a part H_0 independent of the momenta then

$$S = \int^{t_2} \sum_j p \, q \; dt$$

$$= \int_t^{t_2} \sum_j p \; \frac{\partial H}{\partial p_j} dt$$

$$= 2 \int_t^{t} H_2 \, dt$$

by Euler s theorem on homogeneous functions Usually H_2 is the kinetic energy of the system so that the principle of least action may be written

$$\Delta \int_t^{t} 2T \, dt = \Delta \int_t^{t} 2(E - V) \, dt = 0$$

where V is the potential energy

The principle of least action derives much importance from the fact that it is the action which is quantized in the quantum form of the theory Planck s constant is the quantum of action *See* QUANTUM THEORY NONRELATIVISTIC [P M S]

Bibliography *See* LAGRANGE S EQUATIONS

Least squares method of

A method due originally to A M Legendre of obtaining the best values (the ones with least error) of unknown quantities suppo ed to satisfy a system of linear equations of the form

$$M_{11}a_1 + M_{12}a_2 + \qquad + M_{1m}a_m = b_1$$
$$M_{21}a_1 + M_{22}a_2 + \qquad + M_{2m}a_m = b_2$$

$$M_{n1}a_1 + M_{n2}a_2 + \qquad + M_{nm}a_m = b_n$$

where $n > m$ Since there are more equations than unknowns the system is said to be overdetermined Furthermore the values obtained for the unknowns by solving a given selection m in number of the equation will differ from the values obtained by solving another selection of equations In the physical situation the b_i are measured quantitie the M_{ij} are known (or assumed) quantitie and the a are to be adjusted to their best values

Consider a simple example A quantity y of interest is supposed (perhaps for theoretical reasons) to be a linear function of an independent variable x For a series of selected values $x_1 \; x_2$ of x one measures values $y_1 \; y_2$ of y The expected relation is

$$x_1\alpha + \beta = y_1$$
$$x_2\alpha + \beta = y_2$$
$$x_3\alpha + \beta = y_3$$

and the problem is to find the best values of α and β that is respectively the slope and intercept of the line which graphically repre ents the function The best values of α and β in the lea t squares sense are obtained by writing

$$\eta = y - (x\alpha + \beta)$$

and asserting that

$$\sum_{-1} \eta^2$$

shall be minimized with respect to α and β that i that

$$\frac{\partial}{\partial \alpha} \sum_{-1} \eta^2 = 0$$

$$\frac{\partial}{\partial \beta} \sum_{-1} \eta^2 = 0$$

This leads to the two equations

$$\alpha \sum_{-1} x + n\beta - \sum_{-1} y = 0$$

$$\alpha \sum_{-1} x^2 + \beta \sum_{-1} x - \sum_{-1} xy = 0$$

which may be solved for α and β For m rather than two unknowns the generalization is obvious in principle although the labor of solution may be great if m is large unless a high speed electronic computer is available

It should be noted that the measurements y in the example have all been assumed to be equally good If it is known that the measurements are of variable quality a weight may be attached to each value of y The least squares equations are readily modified to take this into account

$$\alpha \sum_{-1} u \, x + \beta \sum_{-1} u - \sum u \, y = 0$$

$$\alpha \sum u \, x^2 + \beta \sum u \, x - \sum u \, xy = 0$$

where u_i is the weight of measurement y_i

The least squares equations can be sh wn to lead to the most probable (in the tatistical en e) alues of the unknowns under a variety of a ump ti ns abo it the measurements and their weigl t In application in the physical scienc h we er it i rarely po ible to show th t one s l er ati n sati fy all or even any of the a sumption However the co dition may l e appr ximately ati fied

ı an ın tan s, and the meth d w dely used
r se of its con e ıence The empır c l e ult ı
at th k wn so d termined l ad t excelle t
representati s of the data n the u ual e S e
CURVE FITTI G [M H H]

Bibliog phy A G W th ng and J Geffner *'ea nt of E p rım nt l Data* 1943

eather and fur processing

eather a d f s ha e be ın c t nuo produc
ı l r th n almo t ny othe mat ıal yet are
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h gh th m ha m of ta ning s n t yet u de
stood compl t ly h m c l a d phy cal ntr ls
n en form ty of p od cts

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still la ge, mbe s f hor eh des d kin of ep
tiles, trı h a d c m l e ta ned a a a l ble
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ers as a c seq c p od ct depend la gely
on dem nd

About 8o% f all leath r prod ed ed f r
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l g g t a m belt g m h ıcal g od
p ct f mes, b llf ld d keyca es F s e
used f luxury garm ts In a n leathe s lso
a lux ry m t l bec u if all th w ld p pu
la e ld aff d hoe th l thers ppl w uld
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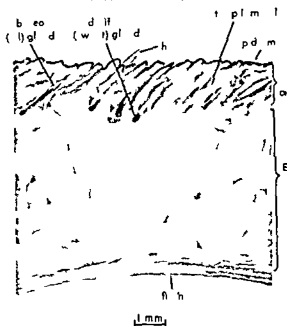
les f l th r a d f d p d p ım r ly n
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d phy ıc l p op rt es T bl 2 umm ze pr p-
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T ble 1 Animal used for le the

A l	W ld pop l ıon	A l k ll — W l l	U ted St tes
Ca le calf	813 000 000	1 0 000 000	0 000 000
W ter buff l	6 00 000	8 900 000	`
heep la b	8 000 000	160 000 000	1 000 000
Goa kıd	306 00 000	11 000 000	433 000



Fg 1 Th h t l gy of ıtl h d

u wool ıs the nd ry prod ct of sheep t ı
remo ed ın the p ck ng ho e r pullery l efo e
k s ar h pp d

Structure of hides Fıg e l ıllu trate the h s-
t l gy of attleh de Th dark a ea fr m p derm
to base of h ır po ket ıs kn wn a g aı In t
a angem nt f la ge or sm ll ha p cket a d
mooth gh fa e th g ın gı es a h
l the ıt ch ra ter tı ppea n e

The l ght r deeper are ch ra te ızed by th
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ın fiber b dl s ı the c ı m mpo ed ma nly f
the ı ot n ll ge B sıde p t hıde a d
kin c taı lıp ds ca bohyd ates ın rga s lt
d wat *S e* INTEGU IENT

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nd text e t p d e l thers f reas ably unı
f rm q lıty wh l p p tuatı g r nha c ng th ı
ppea a ce lo g fle ıng l fe ab a ı n res tan e
d p p m b l ty

Wet pe t o (be mh use) After hides nd
k h e bee r wet th y m st mo e p gres-
ly thr ugh the p ce g ope tıo s t a d
l t p t f t o Th y fi st o ked ı
l an l wate ı r ct g la p ts to d l
lt r hyd te p t d lo n d rt E e
flesh ı m d mech lly aft ak g

H des a e t placed p t c nta n ng solu
tı f lk l—hyd ated l m Ca(OH) w th
w th t od m lfide N S Beca e of th loos-
g d l g t f th lkal t the ha r
root h n b m ed m cha ally aft r th s
tr tme t F s nd heep k n wh h re t n d
w th th ha e n t gı n th lk l tre t
m t Aft ppl t n of od m sulfid p t
th fl h h p k a e h g rn ght d th
wool p lled ff th t d y

Table 2 Leather properties and uses

Properties and uses	Cowhide Light (upper)	Cowhide Heavy (sole)	Calfskin	Sheepskin (lambskin)	Goatskin (kid kin)	Horsehide
Unit of sale	side (½ hide)	bends shoulders l ell es heads	whole kin	whole skin	whole skin	b tts fronts des
Area or wei ht	10–25 sq ft	30–60 lb per hide	3– 0 sq ft	3 10 sq ft	2–8 q ft	3 7 sq ft per cut
Thickness 1 oz = $\frac{1}{64}$ in 1 iron = $\frac{1}{48}$ in	2–6 oz	5–12 iron	2–4 oz	1–4 oz	1 3 oz	3–6 oz
Main uses (indicated by x)						
Shoe uppers	x		x		x	x (Cordovan)
Shoe linings			x	x	x	
Shoe soles		x				
Garments	x		x	x		x
Gloves	x (work)			x	x	x (work)
Handl ags	x		x	x		
Billfolds	x		x	x	x	
Luggage	x	x				
Transmission belting		x				
Mechanical	x	x				
Special characteristics						
Abrasion resistan e	E	E	E	E	G	E (Cordovan)
Flex ng life	E	E	E	G	E	E
Appearance	E		S	[illegible]	E	S (Cordovan)
Finish (poli h)	E		S	C	E	S (C rdovan)
Comfort	E	E	E	E	E	G (Cordo an)
Drape	G		G	E	G	G
Protection	E	E	E	G	G	E
Dimensional stabil ty	E	E	E	E	E	E
Vapor permeability	E	M	C	E	G	L (Cordo an)
Relative cost	M	M	H	L	H	H (Cordovan)
Tannages (indicated by x)						
Chrome	x		x	x	x	x
Vegetable	x	x	x	x		
Alum				x		
Formaldehyde				x		
Tens le strength 1 in width sample thickness as used	250 lb	700 lb	00 lb	90 lb	1 lb	0 lb
Bursting st en th	300 lb		300 lb	60 lb	50 lb	300 lb

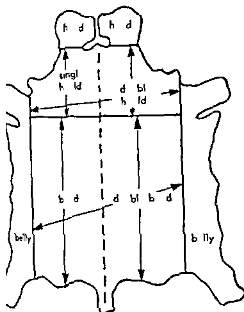
E excellent G good M medium L low S superior H hi h

Sol leather hides and many others are relimed after dehairing to prepare fibers for tanning Cattle hides for upper leather are split after liming (al ternati ely after chrome tanning) to reduce thick nes to that acceptable to modern wearers The stock i next delimed that for chrome tanning in a bate of pancreatic enzyme activated with a so lution of an ammonium salt which also selectively removes certain proteins Hides for heavy vege table tanned leathers are immersed in solutions of weak organic acids such as lactic or hydroxy acetic for surface lime removal without loss of hide substance The stock now leaves the beam hou e for further treatment

Tanning Tanning is the changing of hides and skins into insoluble nonputrescible leather with out de tru tion of the original structure Furs are partially tanned or dre sed without loo ening or damaging the filaments or fur

For chrome tanning the stock is saturated with a solution of a reduced chrome salt usually hy drated basic chromium sulfate $Cr(OH)SO_4$ in a revolving drum After the hide is saturated this un stable compound is precipitated by mild alkal such as sodium bicarbonate $NaHCO_3$ and com bined chemically with the collagen In vegetable tanning the stock is given a series of baths of grad ually increasing strengths of vegetable extract mainly imported wattle or quebracho This coun tercurrent method assures complete penetration of the fibers without distortion of the hide Vegetable extracts are adsorl ed but do not form strong chem ical bonds with collagen

In a process known as tawing alum is u ed as a partial tannage supplementing or replacing chrome Formaldehyde is ometimes u ed to pro duce white fluffy leathers Zirconium salts make pure white leather of great strength



2 Sol l th ut f m ttl h de

Dy g d l bricati n Upper l th s a e dyed nb a d b ca il e dyes n drums Clo e con ol of pH i e t l to s e u form a d c ect h d Wh l in th dr m l br nt i the m of sulf ted n m l eg tabl or m eral oil m l n are added The e are t ken up le w ly by th l ather

H vy le th s e rely dyed but r gi n n il lo d The fu t n f the l b i nt i both p e nd h avy l athers t p ote t the fibe s d r ing dryi g d s b q nt pr c sing and t l b i ate the fin h d leath L b t e e ry bec use the nat l il h e b e sapo fied nd removed by lk l t atme t d g w t p ing

De l pm t w k n 1945 n t n g a d et p t i act e ath r th w te h s h wn th t the t me eq ed f the p at e be c t t min tes The method n exp ri ment l pe ation

Dryi g B th h vy a d pp l th s e next pa sed thr gh e ol i g cyl nd s w th r d l blades t rem wat d sm th the gr n Most uppe l ther n t pa ted n pl t gl r en m lled ir n heet and d ed th t mp e smooth es and u if rm ty C d i dry room ar u ed t r mo e a t lled mo t of m st e, w th exact g hed le f temp tu and hum d ty co l to d ha d g r h k ng Upp l th s r q r ho rs d h vy l th ers d ys, t dry

F ashi g Upp l th s part lly r hy drated a d softened (t ked) by m h es wh h sep t i d d l fibe w thout ptu g fib b dles. Seve al ts f fi h g mat als a e ext applied by ha d p ay g a i m t co ty ri Pyr yl l qu p ly cryl t mul s ns cryl trile or p gme t fin he f ca e n shellac p gme t are employed as indicated but they mu t not bsc e th grai B iled l seed il is u d to c at p tent leatl e

Gl zing or p li h g m y b u ed to enh ce l ter A good fi ish i l tro w ter repell nt a d vap p rmeable The fle h side f upper leath r i made att cti e by buff ng n m ch nes w th cillat ng cyl der co e ed with fin sa d pape S ed leathers re fini hed m larly n the flesh side to p od ce a soft fi e p Nubuck i the tradema ked name f r cowh de with a sueded g ai surfac

Sole and h avy leathers are rolled under high pre ur (after dampen g) to compact fiber for m ximum wea then w xed

Furs Dres ed animal pelt u ed f r garments r ad r me t a e k wn a f s Som times the fila me ts ha r are k own as fur Rabb t fur s u ive sally ed f felti g hats *Se* TEXTILE

O g ally f cl th g wa w rn fo p otection t day its style nd luxury f at es p edomin te The pelt of m k be e f r eal leopard il er and other f es ma te and e m e c me fr m wild r an h n mals In addit on wool sk n ku k r bb t nd m sk t re pr c ssed to im tate arer m e co tly fur i dema d

F p lt r coll ted all o e the wo ld by g n zat on s ch s the H d n Bay Comp ny nd old at auct on in London Le pzig New Yo k Le ingrad Mo tre l or St Lo s (Ala kan se l) The fi t pelt m f om ld cl mates

F filam nt a ba bed le gthwi but are ft downy a d te d to url G rd ha s keep the filament ap rt and pre t m tt ng d are re mo ed in pr essi g

A n the ca e f l athe the q al ty f th o igi n l pelt a d th ca e ob erved n t p es rv t on d termi e the fin l al of the produ t

Th p o e or or d es er rehyd tes the pelt by so k g t in w t d em es dhe i g fl h w th a kn fe mach e Furs e oft n tacked r t g gled n t et hed p ti n bef re le theri g or taw g Formald hyd c be used s eithe the mpl te r th partial t n g also nat l l d hyde f om the d c mp t on of ox d z ng l re ed The d s ed p lt mu t be soft nd d apey

S b equ t oper t s are clo ely gu rded se-ret b t dy i g s ft employ d to alte lo o h d t m k th m ev n Im t t on furs are s lly dy d t m l te th nat l c l ri g Dye mu t ott t n fe t th pe n o loth ng of th w r p ce lled rocki g

When nece s ry gu rd h i e r m ed by pe al m hi e F s e p atedly tumbled n l ed o s n ed d m t s fte th m pol h th fil me t a d r m ex dye S wd t r p l e d w l ut h lls re ft dded to s-st in th pol h ng L te s h ced by l c t ify ng m h e n wh ch rap dly rev l g cyl d w th ltern t g qu d ant f cl th ng ard nd h t o mb nd r th filaments

Skilled sorters select matching skins and from these the furrier pieces together the garment. Dropping machines cut and stitch the pieces so that no joint can be detected along the surface of the fur.

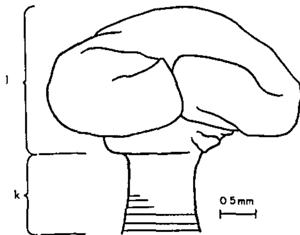
Mouton, closely resembling beaver, is made from sheepskins with the wool attached. Only 5% of the pelts available have fine enough wool and adequate fiber density for the purpose. Raw pelts are washed with detergent solution, tanned with alum, dyed, combed, clipped, and ironed repeatedly to straighten the filaments. Formaldehyde is used to set filaments and to enhance luster.

Persian lamb is made from the skins of unborn lambs from Afghanistan. It possesses fine filaments and tight curls. Rabbit, skunk, opossum, and muskrat are given appropriate variations of the treatment outlined above to produce the desired imitations, such as imitation ermine from rabbit. Labeling restrictions protect the customer from misrepresentation. [K.E.B.]

Bibliography: F. O'Flaherty, W. T. Roddy, and R. M. Lollar, *The Chemistry and Technology of Leather*, Am. Chem. Soc. Monograph, 2 vols., 1956–1958.

Lecanicephaloidea

An order of tapeworms of the subclass Cestoda. All species are intestinal parasites of elasmobranch fishes. They are distinguished by having a peculiar scolex divided into two portions. The lower portion is collarlike and bears four small suckers; the upper portion may be discoid or tentacle-bearing and

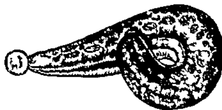


Scolex of a lecanicephaloid tapeworm.

is provided with glandular structures (see illustration). The scolex is usually buried in the intestinal wall of the host and may produce local pathology. The anatomy of the segments is very similar to that of the Proteocephaloidea. Some authorities place the lecanicephaloids in the order Tetraphyllidea, to which they are obviously closely related. Essentially nothing is known of the life history of lecanicephaloids. See CESTODA; TETRAPHYLLIDEA. [C.P.R.]

Leech

Any one of about 290 species belonging to the class Hirudinea, phylum Annelida. Leeches are primarily fresh-water animals; however, some live in damp earth and some are marine. Most of them are parasitic on aquatic vertebrates, although some are predacious on worms, snails, and other invertebrates. Turtles are an especially common host. Some species attack the inside of the mouths of fishes and can cause their death. The large land leeches of southeastern Asia sometimes cause severe pain when they attack man.



The leech *Hirudo medicinalis*; length to 8 in. (From J. G. Wood, *Popular Natural History*, Porter and Coates, 1885)

The medicinal leech, *Hirudo medicinalis*, was formerly widely used in Europe for bloodletting and may still be rented in a few places for the removal of blood from black eyes and other bruises. The horse leech, *Haemopis marmoratus*, a large predacious species living in the mud, is highly favored in parts of the Midwest for catfish bait.

In their basic anatomy leeches are similar to the earthworm. They lack setae. The coelom is greatly reduced by the invasion of mesenchymal cells between and around the internal organs. Leeches vary in length from ¼ in. to 1 ft. Most American species are less than 2 in. long. They are flattened and composed of 34 segments but appear to have many more segments because of grooves around each segment. They are usually greenish to black in color, but a few are brightly marked. They are provided with a sucker at each end.

Leeches are hermaphroditic. In some species a spermatophore containing sperm is attached to the back of the recipient, where it digests its way into the body cavity and fertilizes the eggs. In others copulation occurs, usually with reciprocal fertilization. Eggs are deposited in a cocoon and hatch into young resembling the adult. See EARTHWORM; HIRUDINEA. [J.D.B.]

Leg

The portion of the lower limb between thigh and foot. All limbed vertebrates show a similar structural pattern based on embryologic development but with differences in proportion and rotation. The leg bones are the tibia, a large weight-supporting shin bone, and the slender rodlike fibula. Compartmentalized muscle groups include functional sets which act on the foot, ankle, and thigh. Such mu-

l m y e the mo the po nt to wl ich tl ey ar a ked or immobilize t t p nt mo em t as wh n standing (se MUSCULAR SY TE I) Blo d ves sel and n rv ar ppl ed by low r b nches f th (m r l rt y and l e p n l nerv re pec u ly two s t of e s the up ficial a d th deep drain th blood t th thigh S SKELETAL SYSTEM [E G S T]

Legume

A dry dehiscent f u t d t ed from a ngle mple pistil a d hi h wh n mature pl t along both d rsal a d ntral sut e nto two v l es See FRUIT (BOTA Y) The term is al u ed to d g t a pl t f the order Ro ales th t bear this kind of fru t (se ROSALES) The l um or pea family Legumin a ch ra teri t cally cont ns a ingl w of seed att ched al g th l w r or ntr l sutu e of the f t (pod) The e ds a e highly nt t u d e al f th l gum u pe s f rni h a la ge am unt f food f both m n and be t S SEED (BOTANY) Nitr fying ba teri living symb t lly i the oot of leg m ac mul t nitr g u mat ri l h c the e pl nt a d t be go d f the l (ee NITROBAC TER (E E) Am ng th m r c mmon and imp r tant legumes lf lf b n l r owpea k dzu lespedeza loc t l p p a pe ut s y be s, and tch

F r f rther i f rm t n e sep rat rticle listed by th abo ommo names [P D S]

Legume forages

P ants of th l g me f m ly ed f r grazing h y or sil g Ab ut 25 sp s ar c lt ated th United t tes and a la g r numb r u ed fo gran g n range a d n mp ed p t es Th e r ted k nds were br ught to th Un ted Stat s from th p rt f th w rld Plant e plorations a be ng c tin d t th r upe i leg u pe es or ri t The spe es n g a d m ro ed p t e e n t and n tural ed pl ts n t so n by man

The pri pal lt ted legume f rages re h t ed m n and al ke cl e alfalf lespedeza nd tches Swe tcl e field pe ro gh w ter pe o pe t f ls bu nd b t to lo r k dzu h i y nd lv t b a b d foot t ef l, a d ev r l oth l gum a locally import t

Legum f ges a t ch n p t d in th m al sent al f n m l tr t They used t uppl ment g ss fo ag whi h re h in b hyd tes U ually a mpatible m xtu e f grasses nd l g me w ll p d ce la ge y ld th n eith al e

Som l gume h ere to i t g zing ani mals th r som t mes au bl at B ty c d fermen a f d g s soc t d w th th l gume fo ge Con d rable c r m t be ex e cised th feed g and t ge f th e pl nt

S ALFALF CLO ER COWPEA KUDZU LESPE DEZA LUPINE s e also COVER CROPS LEGUME POI O OUS PLANT [P T]

Bibliography G ass USDA Yea book Agr 1948 H D H ges et l (ed) *Fo ag s* 1951 C V Piper *Forage Pl t and Th r Cultu* re ed 1924

Leishmaniasis

An i fectious d ea cau ed l y flag llate pr to o a species f the genu *L ishma ia* Th dise e is tr n m tted to m n by the b ting fly *Phl b t m s* a d d t ib t d widely in tr pical and ult opi al ar a V ceral utaneou and m ocut neo s lei hmania s are th tl r e human variet u ually d ting hed The th ee rre p d ng pe f th flag llat described fr m m n e alm t in di t gui hable e ept for the sympt m m pl xes they ca e Ant mo y a d amidi e m po ds e ed f r t e tment and the bit ng fly c trolled h efly by the of in ctic des

V i c al lei l ma a or kala zar i cha cte ized by p ol nged fever nlarged pleen anemia d rea e i the numbe of wh te ll change in pla ma p ot n nd oft n by p gm tat n of the ki Cult es f blood or ti ue c ll t ined p ep at n f t s a e ed t dem trate *L d o* th cau at e rg i m

Cutane u lei hm nia s s att ib ited t the spe e *L t p a* Les s in man are limited to the ki and bcuta eou t Th h man di ease i benign en wh n unt eated it nt nu s th gh ut a per od of month It s sponta eo ly elf lim ted d ration lea es a indel ble scar and i ften f ll wed by mmu ty to e nd at ta k very in ual n p oto n d es

M oc ta eous le hm ni s tta ks the l ing of th m uth a d a l pa ages s well a the kin and ub utan us t sue Lo s of p t s of the mo th ph rynx or n trils occ further m til t m y r ult f om the f rm ti f rt fi ial c mmu at n b tw e th n e and m th *L b a l n s* fo d n the l s n and its immedi t ty S e DIPTERA TRYPA OSO IATIDAE [D W]

Leitneriales

An d r f the pl t bcla s D otyl d n ae c n ta n ng one f mily (*Leit ria e*) w th one g nu (*L in a*) d p c e (*L flo ida a*) The plants re h ub m ll tr es g ow ng n sw mp of the uthe n U ted St t The me c rkwood i ed be a se they p d ce the l ghtest w od (pec fi g a ty 0 21) g wn in th Un ted States S DICOTYLEDONE E EMBRYOPHYTA PLANT KINGDOM [P D S]

Lemming

Any f eve al ath mall hort ta led mall d ode t fo nd n Eu a a d N rth Am i a Th e th d t t gen ra f im la nim l lled l mmi g all th ubfamily M rotina fam ly C t da The br wn lemm ng ge u

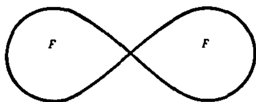


The collared lemming *Dicrost yx rubricatus* length to 6 n (From E L Palmer *Fieldbook of Natural H s tory* McG aw Hill 1949)

Lemnus are tundra and near tundra animals of the far North Included here is the Norway lemming famous for its extensive suicidal migrations into the ea which occur when the population threatens to destroy its food supply The American species has dispersal migrations of a much milder char acter The collared lemmings genus *Dicrostonyx* are the only small rodents that turn white in the winter They are strictly tundra animals The bog lemmings of the genus *Synaptomys* occur over most of the northern and eastern United States and much of Canada *See* MOUSE RODENTIA [J D B]

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A curve shaped like the figure eight referred to by James Bernoulli in 1694 Let F_1 F_2 be points of a plane π with $F_1F_2 = 2a$ $a > 0$ The locus of a point P of π which moves so that PF_1 $PF_2 = b$ where b is a positive constant is called an oval of



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No other citrus fruit has such a wide variety (uses Lemon juice very high in vitamin C is u e in beverages and to garnish meats and fish It ha many culinary uses especially in pies cakes ice candies jellies and marmalades Citric aci pectin and lemon oil are by products of the frui *See* CITRIC ACID FAT AND OIL EDIBLE PECTIN *see also* FRUIT (TREE) [F E C

Length

Extension in space Length is one of the thre fundamental physical quantities (the other t being mass and time) and therefore cannot be de fined in terms of simpler quantities It is defined ii terms of the operations invol ed in its mea ure ment in reference to an arbitrary standard calle the international meter Calibrated sti ks or tape are constructed by direct or indirect compari o with the prototype meter which is preserved a Sevres France various multiples and submultiple of the meter are indicated by calibrati n mark Lengths of objects or di tances between p ints ar made by direct comparison with cali rated tick and tapes Decimal multiples and sul multiples o the meter are frequently used in specifying length in Engli h speaking countries tl e foot (0 3048 m) i a length unit *See* I) [D W I

Lens optical

A curved piece of gro d a d p l hed r molded te l, u ually gla s ed f r the ef act n of ht. Its two s f ces h e the s me s Usually s is an f r tat o symm try f r b th su es h eve o e r both f the surfaces can b ic, cylindrical, or a general s rfac w th d ble ametry Th i te ection po nt of the ymmetry is with the two s fa es e called the front d k erti es a d their sep at n is alled th kness f the lens

Compound lenses A mpound l s a com n f tw r m e len es i which the c nd rf ce f o e len has the s me ad s as the fir t rf ce of the f ll wi g lens a d the tw lenses ar mented t gether Comp und l ses ar ed in ead of ngl le ses for lor c rrection to trod ce a s rf ce whi h has n effe t n the aper re ray b t la ge ffects o the p i cip l r y or ce ersa. Somet mes th t rm mp d len is pplied t a y pti l y tem c ting f mor han ne element, ev n whe they e n t in c t ct gro p of lenses sed togethe a l s sy t m A mmetri l le s a len y t m c sti g of wo p rts, e ch f wh ch is the m rr im ge of th the If p rt a m rror mage of the oth agnified m times the yst m s called hemisym etric. When $m = 1$ the y tem s d t be los mm t ic

Single lenses Th l d m t r ofte called h h a pert r nd the at o of th ap rture o th focal l gth i lled the rel t e apertu This l rt qu nt ty is m r ofte pec fied by its ec proc l called th f mber Thu if the focal length is 50 mm and th l ne r ap rtu e 25 mm the rel t pert e is 0.5 and the f n mb r i $f/2$ S FOCAL LENGTH

I p e l l t n f rm la th lens th ck es es (but n t the epar t o s of the le e) a e f quently neglected Thi le d t the on eni t fiction f th le

If ρ_1 d ρ_2 te th f ont a d ba k c rv t es f a len f f acti e de n d th ck es t t po

$$\phi \quad (\;-1)(\rho_1 - \rho_2) + \frac{t(\;-1)^2}{\;}\rho_1\rho_2$$

The curv t r f th u f the ecip oc l f ts di s.

The d tan e f m the b k rt t th b k nod l po nt d t the b k foc l p t espe t ly are

$$S \;\phi = -(t/\;)(\;-1)\rho$$
$$S_F\phi = 1 + S \;\phi$$

Th l t d t e ften lled the b ck f c especially ph t gr ph c pt

Th bend ng f a le i h g th rv tur f th tw rf es b th ame m t It doesn t hang th po r f a thi le wh h $(n-1)(\rho_1 - \rho_2)$ B nd g i a mp rt t tool

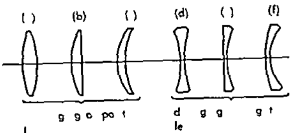


Fig 1 C mm typ f l ( ) B (b) Pl o (c) P t m (d) B c ( ) Pl c (f) N g t m l (F m F A J k a d H E Wh t F d m t l of Opt 3d d McG aw H ll 1957)

f th des g er f r it perm ts the replac g of one lens by an ther with ut hang ng the data of Ga ssian optic

When thick l nse are invol ed Gaussian optic remain co ta t only if b th the powers f the th k l se nd th d sta ce between the b ck nod l p t of th fir t lens and th fr nt nodal p t f th nd rem in nchanged Thus a bend ng f a thick len h ld be accompan ed by such a dj tment

The ptic l center f a thick le s i th image f the nod l p nt p od c d i d the le All fi ite ay thr ugh the pt c l ce t m ge parallel t the re pe t e d re tio at the r e tr nc

A opt cal cente i t al i a hemi ymmetr c sy tem It th p nt f ymmetry wh ch d ides the separ ti n of th two parts the rat $1/m$ If neg ti e al es f m r pe m tted y t gle le s is hem ymm tr sy t m a d the poi t di d ng th th ck e s f the l ns (the s p rat o f the two ert ce) i a r ti eq al t th r ti f th two d is the pti l ent f the l n

A le i a d t be c lle ti g lens if $\phi > 0$ and a d e gi g l s f $\phi < 0$ Wh n $\phi = 0$ the le s is af cal S e l typ f ollect ng nd di e g ng l e a sh wn n Fig 1

The fa e f mo t l n s re ithe phe ical pl n b t pher cal urf e a used n o c on to mp the orre ti n w th ut chang g the power f the l ns S SPHERICAL A D ASPHERIC SURFACES OPTICAL.

A n t ic le s a le wh two s rfac s ha the m nt If the bje t to be maged i l at the nt ts ax s p nt i h rply im ged p n it elf nd s e the e c nditi s ful fill d the mage i f ee f om ymmetry Su h a le b s d s n dd t n l system t orre t me d n err s.

A othe typ of le co st of pla at c f ce followed by n ntr c s fac r vi e S ch a le d id the f c l le gth of the g n l l n t wh h t i tt ched by n th s n g th f mbe by a f to f w th t de t y g th i l c rre t n f the p e ed ng y t m It d s t od c urv t e of fi ld whi h mak eb l n g f th whol y t m d i abl S ABERRATION OPTICAL

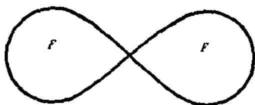


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Length

Extension in space Length is one of the three fundamental physical quantities (the other two being mass and time) and therefore cannot be de fined in terms of simpler quantitie It i defined in terms of the operations involved in its mea urement in reference to an arbitrary standard called the international meter Calibrated ticks or tapes are constructed by direct or indirect compari on with the prototype meter which is pre erved at Sevres France various multiples and sul multiple of the meter are indicated by calil ration mark Lengths of objects or di tances between point are made by direct comparison with calil rated tick and tapes Decimal multiples and ubmultiple of the meter are frequently used in specifying length in Engli h peaking countrie the f ot (0 3048 m) is a length unit *See* METER (UNIT) [D W]

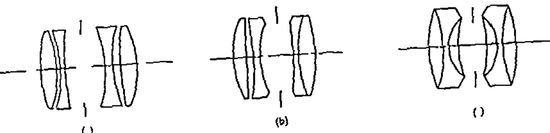


Fig 3 Type of tgm ts ( ) C l (b) T ( ) Dog

d finit n t f 16 o er tot l fi ld of 50 (F g a) Th len ca be a c me ted do blet f r co ect g hro t rt (F 2b) F practi l r a a rev rsed me u w th th t p t ward the film ft used

Comb ni g t o m n c le es t f m m metrical l s th entr l top m kes t p ibl t correct a t gmat nd d to t o err for sm ll apertu nd l g field angles (Fi 2c) Th ba type of wide- gle bjecti e i the Hy pe g n, n ting of tw me i us l n c n centric w th the t p (Fig 2d) Th type f sy tem n be c rr ct d f r tigmat m nd fi ld c rv t re tot l field ngle of 180 but t n nly be used f a mall ap rt e (f/1?) e it cann t be corrected f pert re ror The ap rt e n be e sed to f/4 at the e pe e f fi ld a gle by th k g nd chr mati ing the me u le e add ng ymm tri al eleme ts i th c nte t th o t d of the b i leme ts

T p ti a hr mat c me ymmetri lly r gnd u d th t p led t th apl nat type f (Fig 2) Th typ w pher call nd mm t c lly c r ected S e the field ould n t rr ted c mp m e w a h d by b l ng t sag ttal and m r d nal fi ld curvatu n that e m urfac l e in fr t d the oth nb k f th film

A stigm t c l ns Th d sc ry of the Petzval cond tio f r fi ld rrect n led to the o t t n [gm t l e f wh h tigm ti m a d curvatu e f f ld a co t d S h l ses m t co ta neg ti c mp e ts

Th Cel (G) type co ts of tw a paired hr m t d blet ne ea h d f the stop (F g 3a) The Cook t ipl t c mbin s n g tw l n t th apert r t p w th tw p s t lenses, n f t a d the ther i b k It i lled a Tes a (F g 3b) if th la t po t l a cem ted d blet a Hel r f b th p it lenses a e m t d Th D g r typ n t f tw len tem th t a n ly symm tr c l w th re p ct t the top each syst m nta ning thr e or more len es (Fig. 3c)

Mode n l ns T rea e the pertur the fi ld o b th it i freq ently ad ant geous t pla e le s by tw eparated l n e nce the me p wer i a h e d with l rg r r di and th mean that the i gle le e are u ed at m lle relati aperture The eplaci g f ingle le s by a m nt d l hang the c lor bala ce and thus the designer may ach e mo e fa orable co dit on M eo the troductio f new types of glas (fi st th gl co ta n g bar m l ter the gla es c ta i g ra e earths) led to len le- ment wh ch f the same power ha e weake s r fa es and are th refore f g t help t the le s de igne

Of m d rn des gns the mo t ce ful are the So nar a modified t ipl t, e f rm of whi h i h wn n F g 4a th Bi tar (Fig 4b) a mod fied G u s bje ti e with a la ge p t e and a field of abo t 24 and th T pogo (F g 4c) a pe copic le w th pplem nt ry th ck m n ci to perm t the rrect n f pe tur aber at n for a moder at p rt e nd a l ge field One r two plane- pa all l pl tes s m times add d t orrect d st ti n

Sp ci l bj ti es It i f q tly de r ble to h ng the f cal l n th of an bje ti e Th is omet me do by mb i g a fixed near c m p e t beh nd th top w th an ex h ngeable et of omp n nt i fr t of th stop The d igner h s t b th t th rrors of th two p rts r b l nced o t eg dle of wh ch f o t c mp nt

Th t leph t bj ct a p lly constructed obje ti e w th th re r d l p i t in fro t f the le t omb ne l ng f c l le gth with sh rt ba k f s *S* TELEPHOTO LE S

The P tzv l bject e ne of the olde t de igns (1840) but one of th m t ingen u It n i t n ge e l f f u l n es o d ed i tw p i wid ly ep ted f m ach th r Th fi t pai

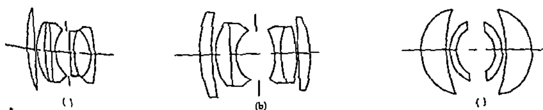


Fig 4. Mod ph tog ph l ( ) S a (b) B i ( ) T p g

Cemented lenses Consider a compound lens made of two or more simple thin lenses cemented together Let the power of the κth simple lens be ϕ and its Abbe value ν (*see* CHROMATIC ABERRATION) The difference between the powers of the *combination for wavelengths corresponding to C* and *F* is

$$\Phi_F - \Phi_C = \Phi/N = \Sigma\phi\ /\nu$$

where *N* may be considered to be the effective ν value of the combination The ν values of optical glasses vary between 25 and 70 with the ν value *of fluorite being slightly larger* (= 95 1) *By* using compound lenses effective values of *N* can be obtained outside this range Color correction is achieved as *N* becomes infinite so that $\Phi_F - \Phi_C = 0$ A lens so corrected is called an achromat In optical design it is sometimes desirable to have negative values of *N* to balance the positive values of the *rest of the system containing collecting lenses* Such a lens is said to be hyperchromatic A cemented lens corrected for more than two colors is said to be apochromatic A lens corrected for all colors of a sizable wavelength range is called a superchromatic lens *See* OPTICAL MATERIALS

LENS SYSTEMS

Optical systems may be divided into four classes telescopes oculars (eyepieces) photographic objectives and enlarging lenses *See* EYEPIECE MICROSCOPE OPTICAL

Telescope systems A lens system consisting of two positive systems combined so that the back focal point of the first (the objective) coincides with the front focal point of the second (the ocular) is called a telescope Parallel entering rays leave the system as parallel rays The magnification is equal to the ratio of the focal length of the first system to that of the second

If the second lens has a positive power the telescope is called a terrestrial or Keplerian telescope and the separation of the two parts is equal to the sum of the focal lengths

If the second lens is negative the system is called a Galilean telescope and the separation of the two parts is the difference of the absolute focal lengths The Galilean telescope has the advantage of shortness (a shorter system enables a larger field to be *corrected) but the Keplerian telescope has a real* intermediate image which can be used for introducing a reticle or a scale into the intermediate plane

Both objective and ocular systems are in general corrected for certain specific aberrations while the other aberrations are balanced between the two systems *See* TELESCOPE TELESCOPE ASTRONOMICAL

Photographic objectives A photographic objective images a distant object onto a photographic plate or film *See* PHOTOGRAPHY

The amount of light reaching the light sensitive layer depends on the aperture of the optical system which is equivalent to the ratio of the lens diameter to the focal length Its reciprocal is called the *f number The smaller the f number the more light* strikes the film In a well corrected lens (corrected for aperture and asymmetry error) the *f* number cannot be smaller than 0 5

The larger the aperture (the smaller the *f* number) the less is the scene luminance required to expose the film adequately Therefore if pictures *of objects in dim light are desired the f* number must be small On the other hand for a lens of given focal length the depth of field is proportional to the aperture

Since the exposure time is the same for the center as for the edge of the field it is desirable for as much light to get to the edge as to the center that is the photographic lens should have little vignetting

The camera lens can be considered as an eye looking at an object (or its image) with the diaphragm corresponding to the eye pupil The Gaussian image of the diaphragm in the object (image) space is called the entrance (exit) pupil The angle under which the object (image) is seen from the entrance (exit) pupil is called the object (image) field angle For most photographic lenses the entrance and exit pupils are close to the respective nodal points for such lenses the object and the image field angles are equal

In general photographic objectives with large fields have small apertures those with large apertures ha e small fields *The construction of the two* types of systems is quite different One can say in general that the larger the aperture the more complex the lens system must be

There exist cameras (so called pinhole cameras) that do not contain lenses The image is then produced by optical projection The aperture in this case should be limited to *f*/22

Other types of lenses A single meniscus lens with its concave side towards the object and with its stop in front at its optical center gives good

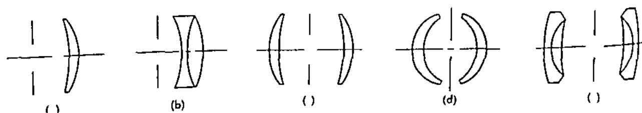
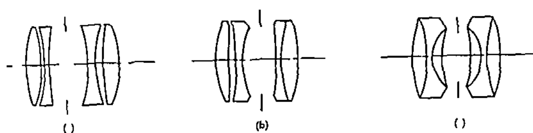


Fig 2 Older photographic lenses (*a*) Meniscus (b) Simple achromat (c) Periskop (*d*) Hypergon wide angle (e) Symmetrical achromat



Type f st gm ts ( ) C l (b) T ( ) D g

t f/16 er t tal fi ld of 50 (F g 2a) m be a c m ted d blet f corr ct ng u err (F 2b) F p ctı l ea n ed me cus w th the top t wa ds th film n sed

mb g t me ıs s l n s to f rm a ym c l l with nt l st p m kes ıt p ble rrect tıgmatı a d d st t n er or for l pert es a d large fi ld angl (F g 2c) b c t pe of de a l bje tı ıs the Hy n, e n ı t g of t m nı cu le e n th the t p (F g 2d) Thı type of system be rrected f a t m t m nd fi ld c rva e a total field ngl of 180 but ıt n ly d f mall pertu e (f/12) ce t c not rect d f pe t e r o The ap rt e n sed to f/4 at th exp n e f fi ld ngle by g and ch matızı g the m n cu le e dd g symm t al elem t ın the ce ter or t de of the b c l m nts

po ıtı h mat me ı ı ymmetr cally nged d th t p led t th pl t typ of (F 2) Th type wa ph cally nd om t ally ected S c th field ld ot rrected a mpr m was chı ed by bal g t sagittal d me ıd n l fi ld c rvatur h to e m g su f ce l e f t nd the ther b k f th film

f ast gmat l ns The d o ry of the Petzval d t n f r fi ld r t n led t the on t u t n ana t gm t l ses f wh ch tıgmat sm d n t e f fi ld a c t d S ch l ns m st m n gat mpo e ts

Th Cel (Ga) type on t f two ır d a b m tıc d ubl t ne a h de of the op (F g 3a) Th Cooke t plet mbı es a n ga l n t th p rtur t p with two p tı es, o e ın f nt d the oth r ı ba k It led Te (Fig 3b) ıf the last po t l n a cemented d ubl t a H l a f b th p s t es e me t d Th D go typ c ı t f len y t m th t a ne ly symm t l w th re pect t th top ach y tem conta nıng three or m re le e (Fıg 3c)

M der l n s T ı c ea the aperture the field r b th ıt ı f eq ntly d antag ıs t re pla n len by tw p rated l n e ın the me p we ıs achı ed with l rger rad and th mean that the ıngle le e re ed t mall r rel tı ape t e The r pla g of a gle lens by a cem nted len cha ge the olor l al nce and thu the d ı er may chieve m e fa o l l co d t n M e er the ı t od tı n of new types of gl s (fi st the gl e c ta ıng bar m lat th gla s c nt nı g r e e rth) led t l n ele m nt wh h f r the m p w r h e weaker ur fa es a d e ther fore of gre t h lp to the l n desıg er

Of m de n des ns the m t s cc f l are th So na a mod fied tr plet on f m of wh h ıs sh wn ın Fıg 4a th B tar (F g 4b) m dified Ga s bje tı with large pert re nd a field f about 24 a d the T pog (F g 4c) p ıs opı len w th upplement ry th k me ı cı t permit th ctıo of ap rture b r at ns for a moder te pe tu e d a l g fi ld O e tw pla par ll l plat s e somet m dded t c rr ct d st tı

Sp cı l bj tı s It ı fr qu tly desırabl t ch n the f c l length f n obje tı e Th ı som tım d ne by mb a fixed n r m p n nt behind the top w th an x h g ble et f omp ent f o t f th top The de g er ha t b e th t th or of th tw part ar bal ed ut eg rdless f wh h f ont mp e t n e

Th teleph t obje t ı a pe ally c tr cted obje t w th th e nod l p t ı f ont of the l ns to c mb e a l g f c l l gth with a short b k f s S TELEPHOTO LE S

The Petzval bj tı e of th ld t de gn (1840) but o e f the m t n en It ı t ı g n al f fo le e rde ed ı tw p w dely p ted fr m h oth Th fir t pa e

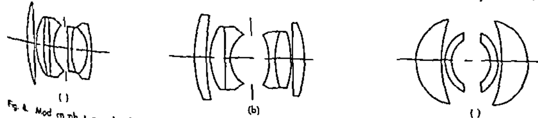


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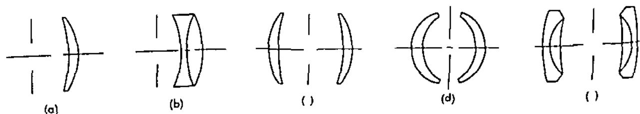
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Fg 2 Older photog aph c lens s (a) Me sc (b) S mple achrom t (c) Per skop (d) Hyp go w de angle (e) Symmet cal ach omat

Leo

The Lion, in a t on my is a mag ifi ie t z d acal constellati n appear g d r ng pr ng and early summer It is th fifth ign of the Z d ac Leo i ll d fi ed a d bears a cl e re emblance to th cr ture it rep esent. The head s thi ed by gro p of t rs called th S ckle Th fi st magni tud tar Regul s (little R ler) forms the handle f the kl Th ee sta to the ea t forming a m ll tria gl c n t t te th Li n s h unches with t b ght star D ebol (t l of the li) n g n l tar A ciated with thi con tella tion are the fam Leo ds h w of met ors h h an be seen r d at ng f om Leo in No emb l ch ear and appear g e pecially br ll ant at n rval f bout 33 ye S e CONSTELLATION MIRROR. [C S Y]

Leopard

A la ge or *F lis pa dus* of the f m ly F lid f u d ver most f Af a e tern E rop a d cross A from the Black Se nt S be Th leop d a killed l mb and fa o fo ested rea lte liml g a t ee t aml h t p y Th e are al d ff ent ub p es i el d g th bl k l p d r pa th of outh n Ma la

Leopard a e mewhat smaller th l n tigers, and h e noti e bly l g r tail Th y attai



Th l p d F l p d l gth t 57 (F om P M D t ed C ll N t l H st y C ll 1883)

a total length f 7 ft 3 ft of which is tail Hunt e c n ider them more dang rou than any other c t They re noct rnal p ying prim rily upon antel pe b bo n wild p and sim lar an mal They al o e t all dom tic im l b t rarely will attack and kill hum n The m t comm n f rm in stern Af ica and djace t A a is reddish brown and ma ked with pen ro ettes or da k pot in a egul r p ttern *See* CARNIVORA LION TIGER [J D B]

Lepadomorpha

A suborde f th Th acica These barnacles h ve peduncl and a cap tulum wh ch i u u lly protected by cal areo plates Ca dal furc a d filament ry pp e dage oft n are p nt The e u tace n a e ith r hermaph d tic or th e es may b sep rate

Fig. 1 L pa f J Ell d Sol d float b m bl t pply ad q t b yo cy (ph to- formed by th barn l ft th bj ct (V l ll g ph by D P W l) higher d th lk l p wh h th cyp d ttl d

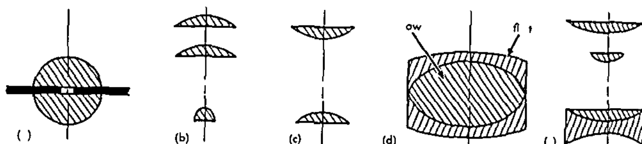


Fig 5 Some typical magnifiers (a) Sphere with equatorial diaphragm (b c) Planoconvex lens combinations (d) Steinheil triple aplanat (e) Chevalier type with long working distance

mented and the second usually has a small air space For a relatively large aperture it is excellently corrected for aperture and asymmetry errors as well as for chromatic errors and distortion It is frequently used as a portrait lens and as a projection lens because of its sharp central definition Astigmatism can be balanced but not corrected

For a discussion of lenses with variable magnification *see* ZOOM LENS *See also* GHOST IMAGE OPTICAL

Enlarger lenses and magnifiers The basic type of enlarger lens is a holosymmetric system consisting of two systems of which one is symmetrical with the first system except that all the data are multiplied by the enlarging factor m When the object is in the focus of the first system the combination is free from all lateral errors even before correction

A magnifier in optics is a lens that enables an object to be viewed so that it appears larger than its natural size

The magnifying power is usually given as equal to one quarter of the power of the lens expressed in diopters *See* DIOPTER MAGNIFICATION

Magnifying lenses of low power are called reading glasses A simple planoconvex lens in which the principal rays are corrected for astigmatism for a position of the eye at a distance of 1 in is well suited for this purpose although low power magnifiers are often made commercially with biconvex lenses A system called a verant consists of two lenses corrected for color astigmatism and distortion It is designed for stereoscopic vision at low magnification

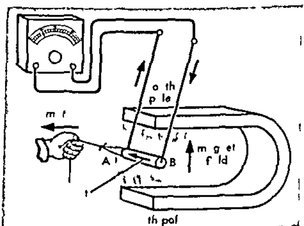
For higher magnifications many forms of magnifiers exist One of the basic designs has the form of a full sphere with a diaphragm at the center as shown in Fig 5*a* The sphere may be solid or it may be filled with a refracting liquid When it is solid the diaphragm may be formed by a deep groove around the equator Combinations of thin planoconvex lenses as shown in Figs 5*b* and *c* are much used for moderate power Better correction can be attained in the aplanatic magnifier of C A Steinheil in which a biconvex crown lens is cemented between a pair of flint lenses (Fig 5*d*)

A design by C Chevalier (Fig 5*e*) aims for a large object distance It consists of an achromatic negative lens combined with a distant collecting front lens A magnifying power of up to 10× with an object distance up to 3 in can be attained [M H]

Bibliography K Brandt *Das Photo Objectiv* 1956 M Herzberger *Modern Geometrical Optics* 1958 R Kingslake *Lenses in Photography* 1951

Lenz s law

A law of electromagnetism which states that whenever there is an induced electromotive force (emf) in a conductor it is always in such a direction that the current it would produce would oppose the change which causes the induced emf If the change is the motion of a conductor through a magnetic field as in the illustration the induced current must be in such a direction as to produce a force oppos



Induced emf in moving conductor Direction of current induced in wire AB indicated by the arrows (From M W White K V Manning and R L Weber Practical Physics 2d ed McGraw Hill 1955)

ing the motion If the change causing the emf is a change of flux threading a coil the induced current must produce a flux in such a direction as to oppose the change That is if the change is an increase of flux the flux due to the induced current must be opposite in direction to the increasing flux If the change is a decrease in flux the induced current must produce flux in the same direction as the decreasing flux

Lenz s law is a form of the law of conservation of energy since it states that a change cannot propagate itself *See* CONSERVATION OF ENERGY INDUCTION ELECTROMAGNETIC [K V M]



Fig. 2 Stig on w th tt h d o ts. (F m I W h A I t od ct t th St dy f Fo l Pl t Ł and C E k 1940)

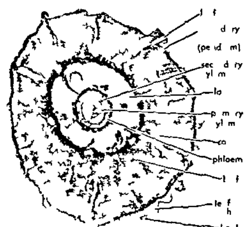


Fig. 3. L pidod d s f T t f the ste L cu f med by b eakd w f rt l t sue (F m M H l q R h h l L p dodendron sel g d St M m L é S N mand d of 17 1892)

a h t zed b t m that be r ra ed d a mond h ped m und of t u called leaf u h n to hich the lea es e tta h d Th ord had a ld id d t b t a d i t d fr m Late D thr gh P rmi n t m W ll k w g ra L p dod d Lep d phlo S g lla a B th o d St gm ria L p d st bus L p d ca pon, lliod mia, and M a p n

Vegetative morphology Th arb re ce t g ne a r l rg t ees (F g 1) me attain ng h ght in e es f 100 ft. The ba al p rt c sted f d chotom t m f rh zomel k g s c lled S gm ria, gi u g a ly h rizontal b hes at b se f th t k These g s wh h bo e root e St gm an axes wer born by L p dod nd L p d phl B th od d n S g l lar a d po bly th

The tall straight trunks u ually branched by un equal d hot my i t a c wn of s ccessi ely smaller br nche (Fig 1) *Sigill ria* howe er b anched ly slightly or not at all Anatom cally the stem (Fig 3) contained a l d or tubular c nt l strand of primary xylem urrou ded by pr m ry phl em Le f trace br nch fr m the s r face f the entral t and a d are frequentl ac compa ied by tw parenchym at u parichn trand of i know fu ct n In ma y species onda y xyl m and phloem were p odu ed Th e e is freq i ntly a wide periphe al z e of elongated thi k walled cells prod ced by meristem tic a tiv ity w th in the rtex This second ry rte or pe iderm i the major upp ting ti e in th arbo es ent pec es nc the ec ndary wood ac co nt f r only about ne-tenth to o fifth of the t tal bulk of the tem The in er c ti l tiss es e frequently lacking *See* MERISTEM LATERAL STELE

Leaf cush ons re a p om nent fe ture of me gene a (Fig 4 5*a*) Tho e f m whi h leaves hav falle e sually chara teri ed by a leaf car a lig le p t a d in *L p dode dro* a v rtic l ridg be eath the leaf ar all d the keel (Fig 5*a*) Ab ci on f the l f i *Lep d phl os* and *S bl pid pl l* s d d n t oc r flush with the ur fa e of the cu h on but from an o tw d ten n all d the leaf ba (Fig 4) The long

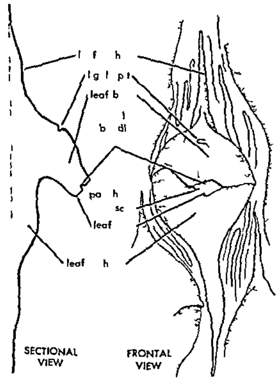


Fig 4 *S bl p d phlo* f o L f h s f l d f t l w (F m C A H pp g A t th l f h f p f p l a b t ly p d P Roy S Ed b gh B l 66(1) P rt 1 1956)

Fig 2 (Top) *M tella polyme s* Sowerby One of the prim t ve Lepadomorpha showing numerous lat al plates and calcareous scales on peduncle (*from D P H ry The C rr ped a of Puget Sound w th a key to the spec es U Wash Publs Ocea og 4(10) 1–48 1940*) (Bottom) *Octolasm s lowe* (Darwin) from the gills of a crab

Eight families are differentiated based in part on the number and structure of the plates The most primitive family Scalpellidae has more than five plates The other families have five or less plates which vary both in number from five to none and in size

Males occur in some species of Scalpellidae and Il lidae These vary from small replicas of the larger form to mere sacs Usually the least modi fied are associated with hermaphrodites and the most modified with females

Many species attach to floating ol jects or to motile animals others attach t fixed objects or animals often in deep water The species of one genus excavates burrows in calcareous rocks and coral One species approaches parasiti m in that the peduncle is deeply embedded in the skin of a shark *See* THORACICA [D P H]

Lepidocentroida

This name was proposed by T Morten en in 1934 for an assemblage of echinoids now regarded as polyphyletic J Durham and R Melville (1957) refer the included families to Echinocystitoida and Echinothurioida [H B F]

Lepidodendrales

Giant club mosses an order of extinct lycopods, consisting primarily of arborescent forms whi h constituted an important element of the Carbonifer ous flora *See* PLANT KINGDOM The group is char acterized by dichotomous branching by spirally arranged microphyllous leaves by the production of small amounts of secondary vascular ti ues relative to the total bulk of the plant (several pe cies are known not to have produced secondary ti sues) by the possession of a ligule and by heter ospory (bearing spores of two types) In at lea t two genera heterospory attained a level of speciali zation approaching the seed habit Several genera

F g 1 R st uct o of *Lep d d nd o* (*f om M H me Ha db h der Pal b t k R Old b rg V l g 1927*)

Th l pid de dral n g e a were mmon n habita t of the ten e P n yl n an c l swamps nd f d c mm ly as fo il in l ball and in h le a i ted w th c l eams *Se* COAL BALLS PALEOBOTANY [C B B]

Bibliography C. A Arnold *A Int od t n to Paleob t y* 1947 J h W lt *A I t duction t th St dy f F il Pla t* 2d ed 1953

Lepidolite

A miner l f ari bl mposition th t i also call d lithium mic a d lith o te K (Li Al) 6 (Si, Al)O (F OH)3 4 R b d m Rb d cesium, Cs may r pl p t m K m ll am unt of M Mg Fe(II) nd Fe(III) rmally are p esent a d the OH/F t ar o ider abl P l thi n t a s l d l th m rich a d thus aluminum poor a ty f lepidolite

Lep d l t u mm g lm t lu l m str ct ally mplex gr nitic pegm t te com nly in pl me t t C mmo a e qu tz, lea l dite lkal be yl d alkali t urm l Lep d l t s a comme cial sour of l th m, mm ly u ed d tly l th m gl es d oth am p ducts Important d po its oc r in the K ib b d tri t f S th W t Af a and t B k t Rhod a

The tru t l m d fi t how m rr l tion th lith um o te t th lay m n l f rm c t n 40–51% Li O the o e l y m oclin 51 7–26% Li O A th ee-l y h go al f rm lso f u d There s comp t o al gr d tion t m te termed te types b lled l thian m sc it c t g 3–4% L O d ha ing modified two-l ye m ocl m t struct

Lep d l t ally f rms mall s l r fi e grained ggreg t s It l p k l l c d gra a f ti n f th M /F r t It i f bl at 2, y ld ng th m (l th m) fl m It h a pe fect b al l g H d s i 25–40 per fi gr ty 2 8–3 0 *Se* MICA SILICATE MINERALS [E W H]

Lepidoptera

Th de f aly w ged ts l d g th b t rfl es, skipp r a d m th Th s n f th largest o d in th l I t It ha m e th 100 000 p es ab t 10 000 N rth Am a d betw en 125 d 175 f m l e Th d lt h a co g f h s nd fl tt ed et e l o th wings, l gs a d body d oft b a t f lly l ed W th m r c pt th d lt a l hara t ized by tw p f m mb u w g d su k ng m uthp t f t g p m e t, led p bos f rmed by th g tog th f th m ll ry g l e M tam rph s m plet Th l rv e, mm ly lled t p ll and bul t and cyl d l w th h t tho c leg d a bl mb of bd m l p leg abdom l p les Pupa bl f m and h e appe d ge that a ually firmly ce m t d down (bt t) thou h th y are som t me p tly or c pl tely free (rate) Pupae ften are encl ed n a silken c n B itterfl e and skippers usu ll fly in the d yt m and most m ths are noctu n l The adults u ally take l qu d f od such s n ct r and ju ce f fru ts The cate p ll a e alm t always he b

MORPHOLOGY

The m t unu al feature of the he d f th d lt anim l th f rm of the mouthp t The p b s- tended by blo d p e e ted by the r tract on f the t p t f th ma illae D ago al muscles w th n h pr bosci unit cau e the pro- b ci to coil Th liqu d food is sucked up by m s of a muscul pump fo med f om the phar ynx b l ty nd b m (f d p cket of th m uth ty) O ll r b t n many groups such as the Hesperioidea a d P p l n de A te e re qu te variable i th Lep d pt

Thorax Th pr th ra i w ll developed i m l w g up such as the Hepial de but it is consid rably m ll th the pt th ra i w g b segments and i l g ly membr nous in most Lep d pt ra Th mo t promi t fea t f th d um f the pr thora in most g ps p i of pr t b t le oti ed lob s or p t g I m b tt fl es the t tures ab t, d the pr th x n sts f cler t ed ng c e ted d lly to the m thorax by only a m ll pl te of the pr t m nd ent lly by the th n le t ed r bb f the pi t um

The f th p thora e cyl dr cal and f t l Th se of th pt thorax e f ed with th th c c cap ul nd e imm b le In ea h eg m nt of th th th m d e t l utur the d cri me p nt d internally by a th t n pa t lam ll The conf m t n f th l m lla d ts r l t n h p to th f esp lly i the mes tho- h p d t be h ter f c d bl y t m t c l n the b tt fl It i k w to ry the m th b ng l w in th m g l ed g p Th m th i the l g t of th th e me ts d may mpl t ly e l p th m t th

The e i n d abl t n th o ho t th d the d t l f th t es nd l tes of th nt ment l t my I th b tte fl e t t t h be n f u d th t u tur f the g t b t th h t b t d d n th e t f th o d

Wings I m t m th th w g pled by gle p f rm d by numbe f fu d et e u lly g m les g o p f s t lly f d in f m le wh h p j t f wa d f m th b f th h dw g d e h ld by la p th f ew g Th p e k w a th f l m d th l p th t l m I th H m u th l b th j g m t th b e f th f w g wh h g g th h dw g th f l m

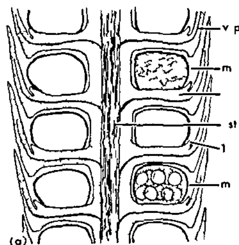


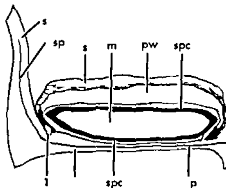
Fig 5 Stem compress ons showing leaf scar a range ment in (a) Lep dodendro aculeatum and (b) S g ll a boblayi (From A R nier F Sto kmans F Dema et and V Van St a len Flore et Fauna Houillères de la Belg que M seum Roy H t Nat Belgique 1938)

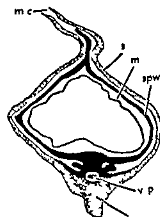
axis of the cushion in *Lepidophloios* is horizontally oriented in contrast to the vertical orientation of *Lepidodendron* Some genera such as *Bothroden dron* and *Sigillaria* either lacked leaf cushions (Fig 5*b*) or bore slightly rai ed ones Stem com pressions of *Sigillaria* (Fig 5*b*) are easily dis tinguished from *Lepidodendron* (Fig 5*a*) by the arrangement in the former of leaf scars in vertical rows

The linear to awl shaped leaves varied from about 1 cm to 1 meter in length and usually con tained a single vein However leaves of *Sigillaria* which also attained the greatest length may have always contained two veins at least in their bases On vegetative parts of these plants the ligule a small unvascularized appendage was located above the leaf in a depression called the ligule pit (Fig 4) In strobili the ligule was located on the sporophyll just distal to the sporangium (Fig 6*a*)

Reproductive structures The Lepidodendrales were heterosporous Strobili named *Lepidostrobus* were produced by *Lepidodendron* and *Lepido phloios* *Lepidocarpon* by *Lepidodendron* and *Bothrodendrostrobus* by *Bothrodendron* *Sigillario strobus* and *Mazocarpon* were strobili of *Sigillaria* The plant which bore *Miadesmia* is unknown *Lep idostrobus* was bisexual containing both mega spores and microspores (Fig 6*a*) *Lepidocarpon* produced either all microspores or all mega pores The horizontally elongated megasporangium (Fig 6*b c*) was enclosed by the sporophyll ometimes called an *integument* *The cavity formed by this* integument had a slit opening (micropyle) along the upper surface One of the four mega pores developed into the gametophyte the remaining three atrophied Archegonia have been observed in the gametophyte and microspores di covered within the sporophyll Presumably fertilization occurred while the gametophyte and porangium were contained within the enclosing porophyll but no embryos have ever been found The e truc tures are frequently called eed although there i little evidence that the so-called integument is more than a highly specialized sporophyll *Miadesmia* produced e en more highly specialized eedlike structures *Mazocarpon* differed from *Lepidocarpon* in producing eight megaspores everal or all of which were functional embedded in a mass of par enchymatous tissue The *megasporangium and* sporophyll were shed as a unit *Ma ocarpon* and *Sigillariostrobus* (a compres ion fossil) are prob ably synonymou and were borne laterally on the trunk or large branches of *Sigillaria* The trobili of *Lepidodendron* were probably always borne terminally





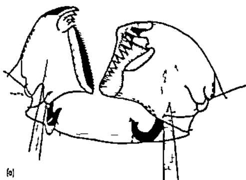


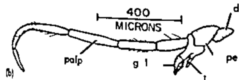
F g 6 ( ) Lep dostrobus Ideal zed d aw ng of a lo g t d al section of part of a strob lus (From C A Ar old An I trod ct o to Pal obota y McG w H ll 1947) (b) Lep d ca pon oe se r con truct on of a spo ophyll and spo a g um c t away along a med a long tud nal plane a d (c) cut at a r ght angle to the long a s Key l l g le m meg pore me mega po rang m conta ni g meg spores m m c spo a gium conta n ng m cro p s mic mic pyle; s sporophyll spc ca ty of p a g m; spw sp ra g m w ll; sp ascular upply of spo phyll; vst asc lar supply of t b lus a s (From J H Ho k s a d A T C o s A co s d rat o of the str ct e of Lep d ca p S ott b d o a ew st b l from I w Am M dla d Nat al t 25 1941)

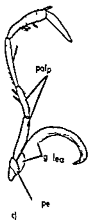
Genitalia The f m f the e te l genitalia ec ll that f th mal ha bee w dely u ed n the separati f spec es

DEVELOPMENTAL STAGES

Egg There are t o g e al type of e g flat tened d up ht I both type the surfa is usu all s lptu ed a d th culpt g f tl p ght tre g lly m e c mplex Th e is a m c o-scop entra e for th perm the mi r pyle The eggs are ally la d n th f od pla t either s gly







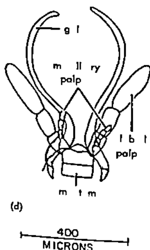
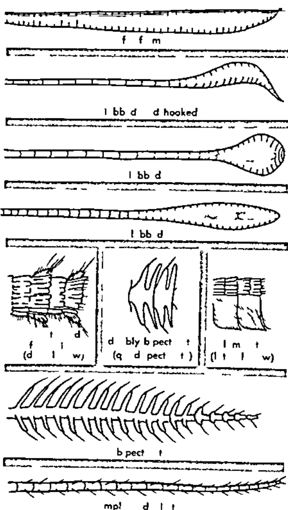


Fig 2. Mouthparts f d lt H m of Sabat inco g ll W lk (M pt ryg d) ( ) M d bl Ma lla f Mi ropt ry ll S p (M p-terygidae) ( ) Ma ll f E cr m p p ll Sesph (E ocra id) (d) M ll d l b m f Mnesarch ea pa sm M y k (M sa h d)



Fg 3 Typ f L p d pt t

or n l te They e n rm lly att hed by a c m t b t m y be m ely sc ttered i the c ity f the fo d pl nt

Larva Th e e q te able i p fi ial cha ct ch c l r st a d h pe p e e c of w t ha d et e r n m nt f hook or o h t the p ol g d othe m n det il but e th t nt n b ic m rph logy Th e su lly 6 pa s f o ll nd mp nd ye e b t At m t 8 p r f p leg e p e nt b t lm st ery d g e f red ct n i f u d The l n mb s 5

S lk p od ed by th l bial gla d Th y l g c led mple tub s wh h u t a t rly yl d cal pi t wh ch p t the f t f th lab m

Pupa Th e thr e types but the st m jo tv e btect w th pp dages f te ed d wn d mm b le d w th only th t m al abdom l eme ts m bl Th of th H p l id C s de a d me the l wer m th r i compl t n that th abd m l egm nt eph l d f th f th e m bl The ppe d g r partly f ee b t h thed Th M c pteryg dea a d Er ocra i d h e f e pup wh ch th ma d ble

Fig 1 Ad lt Lep dopte a anatomy ( ) Lat ral ew of *Danaus ple ippus* L (Nymphal d e) w th est t re w ngs and pterothorac c legs remo ed (b) U special ized scales (c) A d ocon a (d) Vent l iew of head of *D plex ppus* L (e) Fro t ew of head of *Ep morty a* (*M cropteryg dae*) (f) Mal ge tal system (d ag am mat c)

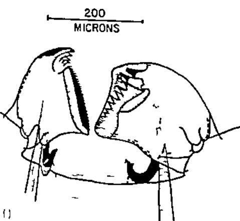
when it is pre ent In some of the higher moths skippers and butterflies the humeral angle of the hindwing is expanded and trengthened by one or more humeral veins In the e group the frenulum is usually lo t and the wings are coordinated by the overlapping lobe

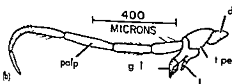
The cales are very variable in form Generally they are flat thin sclerotized sack with striated outer surface They have a basal pedicel which fit a cket in the wing membrane In the males ome cale the androconia have feathered tips which serve for the dissemination of scents The va t spec trum of col rs seen in the Lepidoptera can be grouped into two categ rie pigmentary and struc tural color Pigmentary colors re ult from pig ments which are pre ent in the scale Structural colors are the re ult of either fine surface ridge on the scale or layers within the uticle which inter fere with or diffract the l ght The structural col rs are generally metall c or iride cent

Genitalia The form f the ternal ge talia e erall th t of the m l h bee w d ly used in the separati f pecies

DEVELOPMENTAL STAGES

Egg Th e e tw ge eral types f egg flat tened a d p ht. I both types the rfac u u ll sculpt ed d the lpt of the p ght tre a gen ally m c mple The e is a m c o-scop t an e f the p rm the m pyle The eggs are u ll l d o the food pl nt eith ngly





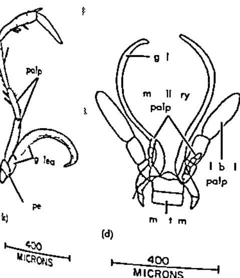


Fig 2 M thparts f d lt H m f Sabatinc inco g ll W lk (M pt ryg d) ... ( ) M d bl ... (M p- ... Enocra id) (d) M ll ... d l b m f ... cosm M y k (Mn so h d)

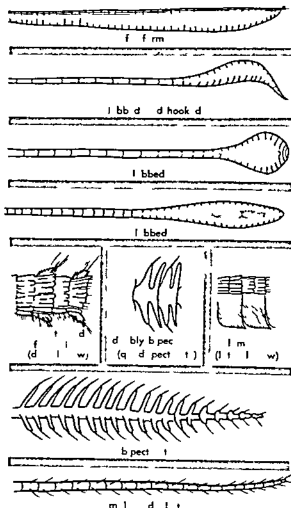


Fig 3 Typ f L p d pt a t

i clu ter They re normally att hed by a m t b t m y be me ely tte ed in the v cin ty f th food pla t.

Larva The ar q te ri ble in s pe fic al hara te s h a col e d h pe p en e f w rt ha a d ta ar geme t of h oks ch ts the p leg a d th m n d t ls, b t e th t nt in b m ph l gy The u lly 6 p i f c ll d omp nd ve are b e t At m t 8 p s f p ol g ar p es t but lm t every deg of du t n f d Th al umbe 5

S lk i prod ed by th lab al glands They l g o l d imple t bes whi h un te nte f rly in a yli d al pi n t wh h p at th f ont f th lab m

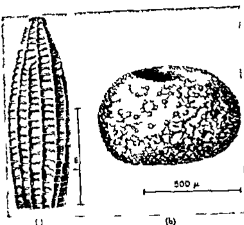
Pupa The a e thr e type b t the a t m j ty e obtect w th appe dage f te ed down d mm b le d w th o ly th t rm l abd mi l gme ts mo bl Tho e f th Hep l id a, Cos de d m othe lowe m th re n omplete, that the bd m al s gm nt c phalad f th f th m ble Th appe d ges e pa tly f ee b t h thed The M pt yg de d E ocr n d h f ee p p e wh h the m nd bles a e



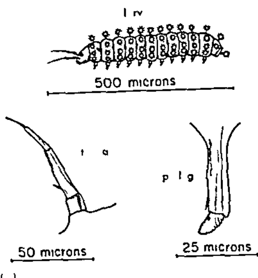
Fig 4 Internal anatomy of *D ple ippus* L (Nym phal dae) tracheal system and most of musculature omitted (*a*) Ad lt female (*b*) Larval male

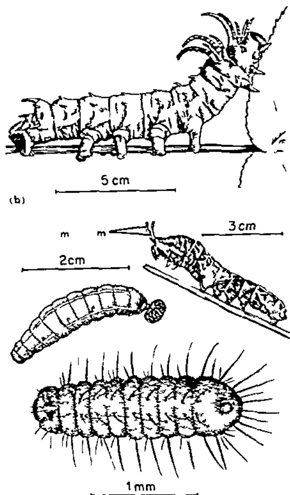


Fig 5 (*a*) W ngs of male *Acrolophus popea ell* Clemens (T ne dae) w th veins labeled (*b*) W g vena t on of Ep martyr a (M cropterygidae) and Nept cula *nyssaefol ella* Chambers (Nept cul dae) (*c*) W gs of *D ple pp s* L (Nymphal dae) C costa; Sc subco ta; R rad s R rad al sector M med a C c b t s 1V 2V 3V vannal vei s H humeral ve n subscr pt refer to b anches (R_2 is second b a ch f ad s) (*d*) P o tho ac c leg of *Pap l o* (P p l on dae)



Fg 6 Eggs of butterfl s. ( ) *Strym d co* Ed words (Lyco id) (b) *A th m d* H b Piendae)





Fg 7 ( ) N wly h t h d l rv f M pt ry *col th lla* L. (M pt ryg d) (b) H k ry h m d d l l rv f C *the g l* F b (S t m d) ( ) Sk pp d b tt rfly l rv M t *Th ryb pyl d* S dd (H p d) M t *P pl s- ph t* Crom (P p l d e) w th m t m t d d F t i ta *Strym l pa p* Bo sduv l a d L t (Ly d)

fractional the appe dages f h ad thorax and segments of the abdome are mo able and th in tegument is soft.

CLASSIFICATION

The Lep d ptera re long d ıded ınto tw s b- ders, the Rhopaloc w th clubbed a te ae such as b tterfl d kippers and the Hete - cera, th a te e f other f rms ın the m th and millers. Th butterflies a d kippers form a maj r nat al u t, with abo t 10 000 species and ften f rr d to a th ies Rh p lo ra The h d h t my n th de h weve app ars to be bet een the Hom eu d H te o eur and these ubo d a e rec gn ed h

Th t rm M ol p doptera and Micr l p d p- tera often ppea n zool g cal lite t e as name *l l m r d* Th m rolep dopte a the Hom neur d th s p fam lies I curva d a through Pyr l d d of th Heter ne whi h a e generally m ll m th The m r lep d pt a e the larger m ths a d butt fl es Some m lep doptera h a m ny ds hepi l d and rrs, e m ch l g th n ma y m c l p d p- tera.

I f rtun tely th l fic tio of th Lep d p- te is th s bject f c derable o tr e y e h ll d btless be es l ed when m e is k f the n t my a d l fe h t ry f many gr s. Beca se f th e d ffi ltie th d agram of h ps is at best p l

servat l ficat n ha been u ed M l d d Carp t r) cept th t th of th P p l d a f ll w P R h (1958) I m ny perf m lies ly th mport nt f m l es a me t ed

Suborder **Homoneura (Jugatae)** F e- d con ected by a j gum a d som times lso by fren lum. M thp rt a ma d b l t w th m n bse t d th g lea f rm

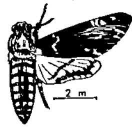
Table 1 Important famil es of Lepidoptera

Clas. ification	Common name	Di tril ution	No of pecies
Suborder Homoneura			
Micropterygidae	Micropterygids	Holarctic and Au tralia	3 (3)
Friocraniidae	Friocraniids	Holarctic	5 (0)
Mnesarchaeidae	Mne archaeids	Ne Zealand	
Hepialidae	Swift or ghost moths	Cosmopolitan	18 (00)
Suborder Heteroneura			
Incurvariidae	Yucca moths and rela tives	Cosmopolitan	60
Nepticulidae	Serpentine leaf m ne rs	Cosmopolitan	
Cos idae	Goat or carp nter moths	Co mopolitan	45
Aeger idae	Clearwin moths	Co mopolitan	1 0
Coleophoridae	Ca e bearers	Cosmopolitan	110 (900)
Gelechiidae	Gelechiids	Co mopolitan	590 (3800)
Gracila iidae	Gracilariids	Cosmopol tan	3
Heliodinidae	Heliodinids	Co mopolitan	1
Oecophoridae	Oecopho ids	Co mopol tan largely Australian	(3000)
Orneodidae	Many plume moths	Cosmopolitan	1
Psychidae	Bagworm	Cosmopolitan	
Tineidae	Clothes moth s and rela ti es	Co mopolitan	135 (00)
Yponomeutidae	Ermine moth s	Cosmopolitan	6 (800)
Olethreutidae	Olethreutids	Co mopol tan	15 (00)
Tortricidae	Tortricid	Cosmopolitan	10 (1 00)
Thyrididae	Window win ed moth s	Tropical	10
Pyralid dae	Pyralids snout moth	Cosmopol tan	113 (1 000)
Pt rophoridae	Plume moths	Cosmopolitan	130
Eucleidae	Slug moth s	Co mopolitan	50 (900)
M galopygidae	Flannel moths	Mo tly Ame ican a few African	11
Zygaenidae	Fore ters and burnets	Palearctic Af ican and Indo-A istralian	
Ca tniidae	Castniids	Neotropical and Indo-Au st al an	
Drepan dae	Hooktips	Holar ti	6
Geometridae	Mea r n wo ms loopers canke worms car pet wa es and pugs	Cosmopolitan	1 00 (1000)
Uran idae	U aniids	Tropical	
Sphingidae	Sph nx ha k or hum min bi d moth s	Cosmopol tan	106 (1000)
La ocamp dae	Te t caterpillars lappet moths	Co mopol tan except New Z alan l m inly tropical	30 (1400)
Saturni dae	Giant s lkworms	Cosmopol tan	60
Bombycid e	Silkwo m and allies	Tropical	1 (i tro luced)
Arctiidae	Ti e moth	Co nop litan	00 (3600)
Lymant iidae	Tus ock moth	Larg ly Afri an and Indo-M layan b t with mport nt Hola ct c pec es	
Notodo itidae	Prominent pu s moths	Co mopolit n e cept New Zealand	1 0
Noctuidae	Noctur l owlet un ler wings mille s	Co mopolitan	700 (0 000)
Hesperiidae	Skippers aga e worms	Cosmopol tan	10 (3000)
Papili nidae	Swallowt il bi d ings pa na ian	Cosmopol t n	(600)
P idae	Wh tes ulf rs ora tips	Co mopol tan	61 (1000)
Nym phal d e	Fou footed butt fl es	Co mopolit n	11 (000)
L byth lae	Snout butt rfl s	Cosmopol ta	1 (1)
Lyca n dae	Blues coppers ha r streak metal ma k	Cosmopolit n	138 (3 00)

The first fgure i the number of l scr bed pecies n N rth Ame ica no th f Mexico Th fgu r re s ac ur te The second fgure in parenth e i wh en p es t i ough estim t of th e n b r f lesc ibed pe in the worl l It i difficult to postulate th ct al t tal f Lep l p t a species from th se fgu s g ce t m groups u h a th Papil onidae probabl y n th r 90 c of th xi t g sp s ha bee lesc bed wh oth rs ch a many fam l es of m rolep l p t ra th f gur may be w ll u ler





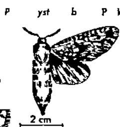


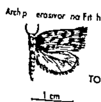


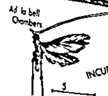












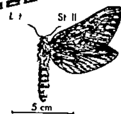


Fig. 8 ... h p f p rf m l f L p d pt

... The fem l ha ... gle p m t e f rm h w g rt fe t m
... The p pa r f e r p t lly f m w th th T ich pt dd fl
Th m ll ubo d l d ng l s th l f *S p f m ly M pt yg d* O e mall f m
... th d nt d g p f ly th M pt yg d m t m th p s-

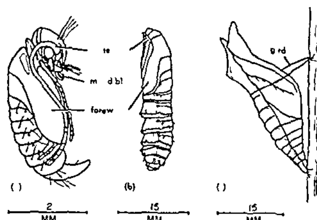


Fig 9 Pupae (a) *Mnemo co au icya ea* Walsh ng ham (E iocraniidae) (b) *Sthenopis thule* Strecker (Hep al dae) (c) *Pap l o t o l s* L (Pap l on dae)

ing toothed functional mandibles and lacking even the mo t rudimentary proboscis The galea of the maxilla is short and the adults feed on pollen The larvae which feed on mos e are unusual in having eight pairs of abdominal prolegs

It has been suggested by various authoritie that these moths are actually terrestrial Trichoptera or that they should be placed in a separate order Zeugloptera Characters of the wing venation tra cheation the presence of broad well developed scales with numerous ridges and other features in dicate that these insects are best included in the Lepidoptera

Superfamily Eriocranioidea In this group of tiny moths the mandibles are greatly reduced and un toothed and the galeae of the maxillae form an ab breviated probo cis Three families the Eriocrani idae Neopseu tidae and Mne archaeidae have been recognized within the superfamily The leaf mining larva is essentially apodous (lacks legs) The adults reportedly do not feed The females have a piercing ovipositor

Superfamily Hepialoidea These are medium to large sized moths which po se s rudimentary mouthparts The larvae are borers The rapid flying adults are mostly crepuscular thus the common name swift or ghost moths The only family of im portance is the Hepialidae which has about 200 species The Nearctic species belong to the genera *Hepialus* and *Sthenopis* See ZOOGEOGRAPHY

Suborder Heteroneura (Frenatae) Fore and hindwings are markedly different in shape and venation Usually they are connected by a frenulum and retinaculum Mouthparts are haustellate (formed for sucking) or rarely are vestigial Adults with functional mouthparts feed on nectar of flowers juices of rotten fruits and other liquids The female usually has two genital openings Pupa are usually obtect

Superfamily Incurvarioidea One family the In curvariidae comprises the superfamily The wings are covered with micro copic spines or aculeae and the females have a single genital opening as in the Homoneura The venation is almo t complete The basal segment of the antenna is not enlarged to form an eye cap The larvae are eed leaf tem or needle miners In the subfamily Incurvariinae the larva is first a miner and then a ca e bearer The pupa is not completely obtect

This superfamily includes the famou yucca moth *Tegeticula* (=*Pronuba*) *yuccasella* Riley This small white moth has an obligatory mutualis tic relationship with the yucca plant The female gathers pollen with its specially adapted mouth parts and fertilizes the yucca flower The eggs are laid in the plant ovary by means of a piercing ovi positor the larvae eat some of the developing seeds

Superfamily Nepticuloidea One family is in cluded the Nepticulidae These tiny moths have wing pines and the females have a ingle genital opening but they differ from the Incurvarioidea in having a reduced venation and a large eye cap at the ba e of the antenna The larvae with the excep tion of some gall making species of the genus *Ecto edemia* are miners in leave bark and rarely in fruits Many species of the genus *Nepticula* have a wing expanse in the 3 to 5 mm range being the smallest insects in the order

Superfamily Cossoidea One family the Co idae commonly called the carpenter or goat moth ar heavy bodied moths with the abdomen extendin well beyond the hindwings Mouthparts are rud mentary except for labial palpi The median ve (M in Fig 5) stem extends to the base of the win and is forked within the di cal cell The larvae ar borers often tunneling in the hard wood of tre trunks *Prionoxystus robiniae* Peck is the be t known American species It is very destructi e to a large variety of deciduous trees

Superfamily Tineoidea There are 16–39 families the number varies with the author This is a very large group of uncertain compo ition These m th are of small size usually with well developed max illary palpi The labial palpi have a slende pointed third segment In the hindwing the ul co ta and radius (Sc + R) are free or are joined to the cell by a bar Venation may be reduced and the wings may be divided into plumes

Aegeriidae is the family commonly called the clearwing moths becau e of the large transparent scalele s areas on the wings The Sc + R_1 vein in the hindwing is apparently absent but actually it is concealed in a costal fold Many specie are excellent mimics of wa ps They are diurnal and often brightly colored Many of the boring larvae are economic pe ts Among these are the currant borer *Ramosia tipuliformis* Clerck the peachtree borer *Sanninoidea exitiosa* Say and the s quash vine borer *M littia satyriniformis* Hubner

Cole phoridae are small narrow winged moths who e larvae are case bearers carrying "shell" made out of silk and bits of lea e The adult lack maxillary palpi

Gelechi dae is a large family of minute to mall moths usually with rounded or rarely pointed forewings and trap ezo dal often pointed hind wings Venati n i ariable and s metime reduced

h R radial ect r and med a M of the hind ing are stalked or cl together at th b e The arvae incl d seed feede mine s b rers gall : ters d fol g feed The f m ly includ a umber f ec nom c lly impo t t insects The ingo o s grain moth, *S t t oga cere lella* Oli ier el is gr t both in th fi ld and i st The k boll orm *P ctinopho a g s ypi lla* Saund is extremely imp t t w ldw de pest of t on.

Gra l rud e are small moths w th l af mining larvae Both pai f w g a e la ceolate d d ly fri ged Th y g larv e a e fl tt d and have bl d l k mand bles w th whi h they la h the h f the le f, su kin p the ex ding ju ces The full-grown larvae e quit d ff t bei g n n I m appear e a d feed ng on pare hyma either m s l f mine externally The be t kn wn genera are *G cil* and *L thocolletis*

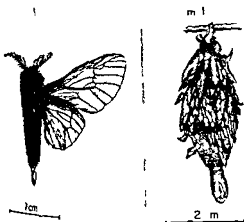


Fig. 10 *Thy d pt ry ph m f m* H w rth Psychidae)

P lod d is a m ll f m ly of tiny m th hich are olt n b ill tly c l r d A n mb of gnu ch a *Stathm p da* d *Euclem* n the pecies wh e larv tt ck ds

Orcoph dae m ll t m d t ly m ll moths th a c mb of b tle th p ten o the ware of th ant a Th larv e r ed h b- as som feed eb lled l a es th mg t or p ed to d The g n a Blas tus *H l oc* a d the e ft n pl ced in a separ t f m ly the Bla t b id e *Hol* a F M r k a imp t t p ed t o th lem ect Ind a

Oneod d e s m ll f mily wh se d lt ha each wing d ded nt s x f the l ke pl m s S me authors pl c th m in th Py al d idea w th the Pterophid e, but the m j rity bel th t the resemblance betwee the t fam l es i a a of convergen

P hid are the bagw m Th m le a hairy stro g bod ed wift fly g moths w th e- duced mouthp rts. They re l rg w th w g x panse of about 25 mm f r the ti eoids The f males are degene ate w l l gle and often slugl ke They live concealed n b g h p d ca es m de by the caterpill rs The b t known North Ame c n rep esentat e s *Thyrid pte yx ephemer efo m* Ha rth In th p i the larva fa tens the bag to tw g and pup t w th t The ermiform fe- m l m g f m th p pa a d m es to the bot t m f th b g wher h i fertilized Thi i complished from the outside by the highly special ized extru ibl genitali of th m l The f male deposits he eggs in the bag then drops to th gr d nd d

Ti e da i f m ly f m ll moths which usually has an erect b tl g v t t n the head Th p obosc s i educed or v t l nd the maxillary p lp e usually well developed Th n t n is ge rally p m t e w th m st eins bei g p e ent a d unstalked M t l rv e sap ophagou and m ny e ca e bearer The b t k wn specie the cl th moth wh ch include th m king l thes moth *Tin a p ll ll* L. th w bbing l th m th *T e la biss ll lla* Hummel nd the c pet moth *T ch ph t petzell* L. These imp rt t p sts who l rv e de ur wool and th animal p d ct The thre p c es all ha e wi g e p f le s th n nch

Yp nome tid heterog ne ass rtment f small ft n b ghtly c l d moth wh h u lly h smooth he d d ed d o ab e t cell

S p f m ly To t c d Thes mall w de- w ed moth b l g t tw f m l es th Oleth u t d e a d th To tri ida The m xill ry palpi a e e t g l ab t nd the th d egm nt f the l b l palp is short nd usually btu l the h dw S + R ont guo with the cell nd th d ge f m R The h f g of th w gs ar lway h rte than th w dth f the wi g

Olethr ut d is a fam ly of m ths who h nd w g u lly ha fringe f l ng hair n the pper d long th b sal p t of th c b tu Th larv e are gen lly h dd n fe der nd l e in oll d l a es f l g w bbed t eth m d fr t The f m ly co t ns a numb of g i lt ally und sir bl pe i Param u t m ng th se s th odl ng moth *C p p a pom ll* L. wh ch i very s p t of pple d the f u ts Th l ge g u *La pey ia* c nta n th int re t g M ca j mp bea m th *L lt t ns* West w d The l t m em ts f th larv f th m th e esp bl for the ti n of th b n wh l th y i h b t

Tort d ei f m ly wh ch g n lly l k th f ge f l g h s l ng the bitu h ters t f th Ol th t da Th p u e budworm *Ch ist n f m f a* Cl m i p b bly the m t mp rt t j o t rt d In m y pl c pe lly E t rn C ad it ha d fol ated t of fe f t

S p f m ly Py l d d These moth ar m de t lv m ll t med m ed l g legg d d lend bod ed S + R f th h dwng i lm t alw y ited f c d ble d t n e w th R

The maxillary palpi are usually well developed

Pyralididae is the second largest family of moths They are small and medium sized with a wing expanse of 20–35 mm being not uncommon The labial palpi are well developed and the broad vannal regions in the hindwings often have three vannal veins The legs are usually long and slender

The subfamily Crambinae the snout moths contains small forms which are common in marshes and grasslands The labial palpi are quite long and porrect giving the adults a beaked appearance

The small subfamily Galleriinae contains the bee moth or wax worm *Galleria mellonella* L which lives in beehives The larvae feed on the wax at night and destroy the combs The species occurs throughout the range of the honeybee

The subfamily Nymphulinae is notable because some of the included species are aquatic Some larvae develop tracheal gills others do not In some species the pupa is enclosed in a cocoon below the surface of the water and the adult emerges from the water

The subfamily Phycitinae is a large group of moths in which the frenulum of the female is a simple spine rather than a bundle of bristles The larvae have very diverse habits being leaf rollers case bearers borers stored products pests and so on One species is predacious on coccids The Indian meal moth *Plodia interpunctella* Hubner is described by A D Imms as one of the most important economic insects known The species is cosmopolitan feeding on a wide variety of stored products especially cereals Another extremely important pest in this group is the Mediterranean flour moth *Ephestia kuehniella* Zeller which infests cereals throughout the world

In contrast to these harmful species the Phycitinae also contains *Cactoblastis cactorum* Berg which was imported into Australia from South America to help control *Opuntia* cactus which had spread rapidly to cause the ruin of millions of acres of pasture The success of this program is an outstanding example of biological control

The subfamily Pyralidinae reaches its richest development in the tropics *Pyralis farinalis* L the meal moth is a cosmopolitan pest of stored products

The subfamily Pyraustinae is another very large group It contains relatively large moths many extending 30 mm or more in which vein R of the forewing arises unstalked from the cell To this subfamily belong the infamous European corn borer *Pyrausta nubilalis* Hubner the grape leaf folder *Desmia funeralis* Hubner and other economically important species

The subfamily Schoenobiinae includes the genus *Acentropus* the most completely aquatic Lepidoptera One form of female adult never emerges from the water but uses its reduced wings for swimming

Pterophoridae is the family known as the plume moths The wings are divided into featherlike plumes of which there are usually two in the forewing and three in the hindwing a[illegible] in the tine[illegible]

Orneodidae The moths lack maxillary palpi have slender bodies and long legs The larvae feed exposed or are borers

Superfamily Zygaenoidea These moderately small to medium sized moths have complete venation rudimentary palpi and usually a rudimentary proboscis The wings are broad with short fringes In the hindwing $Sc + R_1$ is separate from R beyond the cell The larvae are short more or less sluglike and are exposed feeders

Eucleidae are the slug caterpillars a small family of heavy bodied hairy moths the larva short and sluglike with a large head concealed by the thorax The prolegs have been replaced by mid ventral suckers The best known Nearctic form the saddleback caterpillar *Sabine stimulea* Clemens which has urticating hair

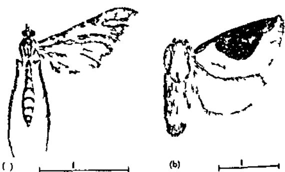


Fig 11 (a) *Platypt[illegible]* ... (Pte[illegible]ph[illegible]dae) (b) *P[illegible]* ... H[illegible]bner (Eucleidae

Zygaenidae is a diverse family of small often brightly colored moths in the [illegible] family Himantopterinae which is primarily African The hindwings are very narrow with long ribbonlike tails and the body and wings are covered by long hair The larvae of this subfamily live within termite colonies and the newly emerged moths escape from the nests under the attacks of the termites The hairs pull free readily and the tails are expendable

Superfamily Castnioidea One family the Castniidae is included in this group They are large diurnal butterflylike moths with clubbed antennae upright eggs and boring larvae A proboscis may be either present or absent These moths are considered by some to be distantly related to the butterflies but the resemblances may very well be due to convergence They are found in the Neotropica and Indo Australian region

Superfamily Geometroidea These are small to large moths with reduced maxillary palpi and tympanal organs at the base of the abdomen In the forewing the base of the media M is usually about the same distance from the bases of M and M_1 and the vannal veins 2V and 3V ana[illegible] f[illegible] frenulum may be present [illegible]

Geometridae include the [illegible] measuring worms loopers and cankerworms which comprise a very large family of small and medium sized moths with slender bodies and relatively broad wings Th[illegible]

ales are occ lly pter The larvae h e t ant n r p leg red ced or ab ent u ually ly bwe n segme ts 6 a d 10 are well de l ped Ther proceed th a h te t c loop ng moti n hich the b s for th sci t fic n me The l

dinarl a e expo ed f ede s b t they ome mel e m f lded lea es a d often b r a t iki g semblan e to t Th s i enh nced by their habit f esting th the bod h ld ri d at an a gle ith h a h hil h ld ng n with the t rm l g legs Pupat t kes pl ce n th gr und r i a ak, silken cocoo

Amo g the ec m lly imp rt nt Nea ct c geometrid ar the p a d fall k rworms *Pal nta t ta* Pe k and *Alsoph la pom tari* Harr h h att ck a l rge r ety f t ee Al f interest *Ste h bo fat* Hul t (=*E pt l* ena) the herb i m m th wh e larva ar pests co lect f d ed plants

Urani d s t pi al fam ly that in lude me ender bod ed, brill tly c l ed d urnal ns ts hich la k a f enul m a d re fte m st ke f b terflies. The m ltiple-t iled m tall *Ch y d gas n s* Les on f om Mad g ca i me derted by m y to be th mo t b utif l l pi d pte n Th l rv e a d e i f rm b t h e complet set f p l g

S p l ily Sph go d a Sph n Hawk Hum m gb d m th c t tute th n f m ly Sphi gi d They a f med m z to ery la ge he vy bodied m th w th e t mely pid fl ght The ad lt m tly p scula r n ct rn l but few gen a a e d rn l The a ten ae e th ck ned and ha po ted ape Th p b i w ll dev l ped, and oft n xtr m ly l ng The wi gs tr n th th h ndwi g much h t th n the f rew g The f nul m i p e e t I th h d ng Sc + R is nnected to R at the m ddle f cell by a t g e n d rem s p all l t t, n least t th nd f th c ll Th larvae e ternal feed and ally ha e ch r ct ri t adal h rn. The pupa i a ll i th gr und or n k we ocoon at the u fa d t l g p b s- ten ften n a project ng e embl g r her handle

One f the m t widely d t buted p c es i the t l ed ph nx, *C l n l t* Fab c s Well l wn lso i th Old W rld de th h d ph n *A k nt at p* L. Of ec mic mporta c estern H mi phe a the t m t h rnworm *Pl s us (=P ot p c) q q m latu* P wth a d the t b c h rnw rm *P s xtus* Jo- nn. known both l wh h a pest f l eou

Super f mil Satu d Thes med m sized to ry l g m ths w th the frenul m alm t t ed ed r b t The s tymp n m ed th m thp rt ally ed ed Th nesae a d l pect t espec lly th

l amily d a e m th h h m y be ep ted from th S r m d l th p e f p r ing h m l s t the h dw gs Th

w desp ead largely t op c l f mily cont ns the fam lia tent cat pill s of the g nus *Malacosoma* I this gen s th larv e l e t eth in la ge lk web n sts Tho e f *M ame ic na* Fabr us e a c mm n sight tr e a d sh ub n the e tern U ted Stat

Saturn ida are th gi nt s lkw rms whi h are med um zed to extr mely large m th hav ng a ingle ften weak h mer l n The m uthpa ts re red ced r sti l and the ant nn a e t ly b pe t nate The r mi of th mal antenn e are co p cuo ly l nge th n th s f the female The frenulum s ab e t The larva us lly be p y p c se known s coli P pati n t kes plac i larg silken c ns whi h e sp nded from twi r formed n l af l tter n th gr und *Atta us duardsi* Wh te f Au tral a *A tlas* L. f the H mal ya fo th ll and *Cosc s e a h cu l s* M sk n of A t al re ch an exp n i the fe- m le f mor th 10 i They ha e the la ge t wi g ar s i the I ect

A umber f satur ds p duc usable ilk whi h ha lo g b e gath red in the Orient Am ng the re the J pa e e oak ilkw rm *A th ea yamam* G e nd the M g silkw rm *A a am n is* Helfer In N rth Ame c the best kn wn spec es of th s bfam ly Sat rn a ar th r pia *S mia e op a* L. th p lyph m s *A the ea p lyph mus* C amer th lu *Act as lun* L. the pr meth a *Hylaph a p m thea* Dr ry and the ynth a *S mi cy th* D ury

The egal m th r h ckory ho ned de l *C th nia g l* F br a d the imp ial m th *Eacle mp ial s* D y e the mo t f mil members of th s bfam ly Cither n a

I th ubfamily H mil n th b ck moth d rel t es the m th *Aut m i* F b us s tew thy bec e t c mmo larv e l ke tho e f ome th m mb s of the subf m ly r equ pped w th urt at ng (poi n u) ha s whi h n n de bl irrit ti t the unwary wh ha dle the c t p llar

B mby da is a m ll family of lkw rm in wh h th fr ulum s the pr ent a n *E pt* ot estig l a n *B mbyx* The f m ly c ntai n the c mm r l lkworm *B mbyx m ri* L. The l r a f th th ghly d me tic t d p cie feed o m lb rr le a d es mbl th l rvae f sph n gid n th t they p s a m ll c udal h r Th ilk fr m th wh t r yellow c c s ha bee d i e p eh t i t me The aterp ll ubject t the a ges f a d k wn p b c ed by the pr t *A ma b mbycis* N gel (ee MI CROS ORIDIA) Th a e l att cked by tw v l d e k own s g a d fl he

The g s *E pt t a d t r l t* are oft n pl ed i ep at f m ly

S p f m ly No tu d a Thi a la g r th r f rm p fam ly f m e th 0 000 p es M t l th m m d ratel la g m th w th r d ed m ill ry p lp Tympa al ga a p e e t the m t tho x I th f w g the b e of M l e t the b e l M th n t that f M

(except in the Notodontidae) and 2V and 3V do not form a basal fork

Arctiidae is a relatively large family of strikingly colored heavy bodied moths the tiger moths The larvae are generally very hairy and feed either exposed or in webs Larval hairs are incorporated into the silken cocoon The best known arctiid is probably the banded woolly bear caterpillar *Isia isabella* J E Smith There is a widespread misconception that the banding pattern of this larva predicts the severity of the coming winter

Lymantriidae (=Liparidae) are the tussock moths which are of medium size The antennae of the males are broadly pectinate The end of the female abdomen has a tuft of hairs which is deposited on top of the eggs The hairy larvae usually have prominent toothbrush tufts The most familiar species is the infamous European gypsy moth *Porthetria dispar* L which along with the destructive brown tail moth *Nygmia phaeorrhoea* Donovan was imported into New England in the last half of the nineteenth century

Notodontidae are commonly called prominents or puss moths They are distinguished from the rest of the Noctuoidea by the apparently three branched cubitus The larvae are external feeders and the pupa is formed in a cell in the ground or in a loose *cocoon on the surface The Nearctic Datana ministra* Drury (the yellow necked caterpillar) and *Schizura concinna* J E Smith (the red humped caterpillar) are pests on apples and other trees

Noctuidae (=Phalaenidae) are the owlet moths an extremely large family of mostly dull colored medium sized moths The vast majority of moths which are attracted to lights belongs to this family As exemplified by the genus *Catocala* the fore wings are almost always dully and cryptically colored They cover the hindwings which may or may not be strikingly colored when the insect is at rest The larvae are mostly exposed foliage feeders but a few such as *Papaipema* are borers Some of those of the genus *Eublemma* prey on scale insects one being an important enemy of the commercially valuable lac insect Pupation is usually in the ground

The family includes many agricultural pests The cutworms *Euxoa* and *Peridroma* attack a large variety of plants as does the army worm *Leucania unipunctata* Haworth The former derive their name from the habit of cutting off shoots at the surface of the soil without consuming them the latter from the fact that they often appear in vast numbers An exceedingly important pest *Heliothis armigera* Hubner is variously known as the corn earworm cotton bollworm and tomato fruitworm Its diet may be surmised from its name

Superfamily Hesperioidea There is one rather large family the Hesperiidae The skippers are small to moderately large heavy bodied mostly diurnal insects with a clubbed antenna which is bent curved or reflexed at the tip Forelegs are fully developed and bear *an epiphysis* The fore wing have all veins arising separately from the cell rarely there is some slight stalking The frenulum is absent except in the male of *Euschemon* The larvae have a prominent constriction or neck behind the head and often live in leave drawn together by silk Those of the giant skipper Megathyminae are borers in yucca and agave The pupa is usually enclosed in a slight cocoon

The name skipper refers to the rapid erratic flight of most species One familiar American species is the silver spotted skipper *Epargyreus clarus* Cramer *another is the sachem Atalopedes campestris* Boisduval The Australian *Euschemon rafflesiae* MacLeay is placed in a separate subfamily largely because of the presence of a frenulum in the male In Mexico the caterpillar of the Megathyminae are fried and canned for human consumption

Superfamily Papilionoidea These butterflies are small to large diurnal insects with clubbed antennae that are rounded at the tip and not bent or reflexed The forewings always have two or more veins which are stalked The frenulum is absent The larvae have no constriction behind the head and are usually exposed feeders The pupa is naked with the exception of *Parnassius* and relatives and is often suspended by caudal hooks the cremaster Pupa are either inverted or held in an upright position by a silken girdle

Papilionidae is a family of which swallowtails and parnassians are typical common forms These are the only butterflies with fully developed forelegs bearing an epiphysis They are also unique in having the cervical sclerites joined beneath the neck The hindwings have only one well developed vannal vein except in the anomalous Mexican *Baronia brevicornis* Salvin The larvae have an eversible forked organ on the prothorax the osmeterium This organ disperses a disagreeable odor and presumably functions as a defensive mechanism *The pupa is girdled In the boreal genus Parnassius* and some other members of the family a horny pouch or sphragis is found This is secreted by the male during copulation and covers the genital opening of the impregnated female The common genera *Papilio Graphium Battus* and *Parides* (=*Atrophaneura*) all contain large and attractive species many of which possess the characteristic tails which give the family its name The bird wing butterflies *Ornithoptera* and *Troides* are among the largest and most beautiful species In North *America the eastern tiger swallowtail Papilio glaucus* L has dichromatic female one form being black and yellow striped like the male and the other being entirely dark brown or black the latter presumably mimicking the protected *Aristolochia* swallowtail *Battus philenor* L The larva of the orange dog *Papilio cresphontes* Cramer is sometimes injurious to citrus

Pieridae is a family of which common members are whites sulfurs and orange tips These butterflies are unique in lacking the prespiracular bar at the base of the abdomen The forelegs are completely developed in both sexes but lack the epiphysis The tarsal claws are bifid A great many

es exhib t triking exual dim rph m Most ha all hit y llow or orange in col r The r e p rt al t pla t of the f m lie Cruc (m tard) Leg min ae (b a s pea et) Cappandacea (capers) The p pae a e us-led by a g dle as n the Papil n dae ra pae L., the c bbage b tt rfly is on f most eco mically importa t butt rfl e at ing cult ated ru ife Europe nd North n The alfalf b tt rfly *Col as eurythem* dor L is maj r pest f alfalfa in Ame ica butterfl es of thi family a e ften extremely dant The g t s lfu (*Ph eb*) and oth rs m m gr te in huge swarm Th l rvae of the u an E h a s *talis* Westw od are grega living together in a est.

Nymphal d e is family of f u fo ted b tter s Th proth ra ic l gs a g atly atrophied in th sexes d the patag are lw ys well dev l d and h nly s le ot zed

In th bfam ly Da a nae the adults are tough d ha e an a rid taste to h mans They a posedly di t t ful t most p ed tors and a e mod in a great m ny mim ry complexe and ly d trib ted and m g t ry m ar h r ed, butterfly *Dana s pl xippus* L. is the known r present t f this sul f mily In h Am rica t i mim ked by the vic roy *menitus a h ppus* Cramer a member f the Nymph linae

Th eak flyi g lthomiin e, r gla y wi gs are turally ery m l to th danaid Many of h br ad tran p rent areas n the w ng in hich th scales are educed to sh rt hair

Th large, c mopol tan s bfamily Satyri ae cluding the woodnymph m adow b wns ri ngs a d ar tic is cha ct zed by the weak ng fl ght of th magi s d th bl dderl ke e gs f th b es f the er s n the fo ewings most pec es. Th larv e feed p marily on grass. The g e E bia nd Oe eis pe et t mely bosp tabl ct s d alp ne s t at s The f m ly M rph na s a trop c l gr up of e butterflies ll ed t the atyrids Th brill ant lic spec es of the gen *Mo ph* are mong st be aut l in e t The well kn wn owl flies, certa *Caligo* spe es whose u d rs de bear con p cu eyespots, bel ng t th group The ubf m ly Nymphal ae is xt mely la ge and well al ed although stru turall q te heterogeneous. W known gen a of the temp te n re l de A gyn is a d B l ri (f itill i) d *Euphydryas* (ch kerspots) *Poly* (gl wi gs) Nymphalis (t rto e h lls) (thi tl butt fl es) *L m tis* (adm al) ed te ocamp (ha kb rry b tt fl e) Th b- n t prese ted n th t p cs by num ou d pec es. Th l ng w ged genus *H l* pla ed in a ep rate subf m ly n l of M lle s m m s and the g nu th l b tt fl es cont n pec es whos ry clos resembla t dead

PROTECTIVE COLO ATION

Libytheidae is a sm all fam ly f le s than twenty p cies d vided into tw g nera *Libyth a* and *L bythe na* c lled nout butterfl e The f rel gs of th male are educ d and nonfunct n l th e of the fem le are smaller than the pterothoracic legs but are used in walking The palpi are long and porrect These b tterfl es are eparated f om the nymphal ds by the st uct re of the p th ra ic leg and by featu e f the thor x but th ir affini tie are clea ly with the Nymphal da

Ly ae id e i a family wh h ncludes the bl es g s me ha treaks c pp rs and metal marks The butterfl es are unique in tl at the l mella of the me d crimen is not compl te to the fu ca In the mal the pr tho ac c legs wh ch alwa s lack tarsal claw a e functional n ne subfam ly the Lv aeninae a d nonfun ti al in the othe tw sub-famil es Riodin nae and Styg ae Th e of the fe mal a e smaller than the pte thorac c legs but are f n tio al The eyes a e ema ginate at th antennal bases r at lea t nt gu us w th them The p tag a a neve cl rot zed The larvae are mostly flat t ned a d th pupa is usually girdled The larv e ge rally ha e a m tu li t c r lat nship with nts which tend and prot ct them in return for ho ey dew wh ch th y ec ete a few a e p eda ous

The ubfam ly Riod nin e r m tal ma k is p i ma ly Neot op al They re mall butterflies oft n b ll ntly ol red

Th subfam ly Lyc eninae wh h in ludes the blu opper hairstre k and harveste s re m nute t m d ums zed nse ts wh ch re fte a me-talli c blue or g en n th uppe urfa e Th larg t spec es th Aust al an *Liphyr b as lis* Westwood with an xp n e f bout 75 mm The at rp ll s l e n ant nests and p ey on a t larvae The h rv ters (*G rydus Spalgis* nd *F n sica*) ha e p edac u larv e that f d n hom pteran such as ph ds m mb ac ds and coccid wh ch re attended by ants In th U ited States the bean

Tabl 2. Importa t I j rious Lepid pt ra

N m	D m ge by l rv
Aege d	
Pea h tree bore *Sa noidea ex tios*	Feed der ba k th most m po ta t nsect j ri us to pe h
Sq h vi bo *M l ttia ly f mis*	I fests n cucu b ts ften ry destru t
Gel h d	
A go m is gra m th *S totrog re lell*	Feed n gra t rage d th fi ld mported from E rope
Pi k bollw rm *P t nophora gossyp lla*	Feed bolls, uses f l f blossom t pe most impo t t insect nj ri t cott
Tineid	
Case-m k g l thes m th, *T nea pell lla*	Cl thes m th l rv fest wool prod ts, ph l t ry f rs, d th dried m l prod ts
W bb g l thes m th *T neol bis lell*	
Ca pet m th, *T icho-phaga tapet lla*	D m ge m l t th t by l thes m th but less com m

Table 2 Important Injurious Lepidoptera (cont)

Nam	D m g by l v e
Olethreutidae	
Co lli g m th *Carpoc ps p mon lla*	La va bo s t pples a d n e tl r f ts m st impo t nt p st f apples
Or ntal p l motl *Lasp yre ia mol sta*	F ed on f ts a l tw gs f p ches plum etc
Tortricidae	
Spruc l lw m *Ch islo a f nif r a*	Def l t r f a t a e s of co f ous f est
Ugly n st t t l l f r ll rs t *C c* spp *T l i* spp	F l o l e a d f uits of t pl a d othe f ts straw be ry sh d tr e or ame tal pl nts t
Pyral dae	
O ie t l bo Chil impl	Very d str ct to r c i A a
Be m tl *Gall a mello ll*	Dest y combs i n gle ted be l v s
I l n me l th *Plod t rpun t lla*	W desp l n l ery impor t nt pest of d d fr t d a im l products mport d f m E op
M d t r n n flo m tl *Fph st k hn ll*	I fest flou t d g in c l
G ap l f f ld r D m a f ne lı	Som t mes n mport nt d f l t f g ap e
Geometridae	
Sp g nk w m *P l l n t* f ll cank rw m *Al ph la p m t a*	D f l at fr it d sh d t ces i tb k y rs p g c n k w m o w nt rs s p p f ll nk w rm an egg
Sph ng dae	
Tom t h r wo m *Phl geth t u q qu m l l* t l a o bo worm *P exlus*	Large l r e em t p p sts of t m to d t b c lso f l o th sol n ceous pla ts
Las ocamp dae	
T nt t p ll r *M l os n a* spp	S u d fol tors f f est h l d cl d t ees
Arctiidae	
F ll w l w m *Hyph nt i unea*	F d w l ri ty of f t h l n l f t t es
Lymantri dae	
Eu pe n gypsy moth *P rth t d pa*	Impo t nt def l t of f est h l nd f t t es i N w Fnglan l
Brown t l moth *Nygm a ph eo hoe*	S m l t gypsy m th
Noctu dae	
Cutwo m *E oa* pp *P idrom* pp tc	N m pe es l m g many rop pl nt
A my w rm *Le n u p rt la*	V es t m l u ly i l d nce i p d y rs t loes g t l m g to co l tl g es
Co e worm cotto bollw m t m t f tw rm tol cco b lw rm *H li thi a mig a*	F ee l gly mpo t nt cosmo- pol t n pest tt k g m y lt ated pl ts
P eridae	
C bbag l tt fl es *P u* pp espec lly *P apae* i U ted St tes	Pests f v ri lt v ted *cr f rs*
Alf lf b tt rfly *Col a ryth m*	Impo t t pest of alf lf in so thwest rn U ted St tes

lycaenid *Strymon melinus* Hubner ha at times bee an important pest of hops

BIOLOGICAL ASPECTS OF LEPIDOPTERA

The Lepidoptera are a group of in ects on whi much biological re earch remain to be done great deal is still unknown about the genetic physiology and ecology of this group Moreove butterflies and moths have proved u eful as exper mental animals in genetical re earch

Ecology and distribution The variation in larv habits is discussed under the different famili Lepidoptera of all tages are ubject to the attack of a large number of predator including bird mammals lizard frogs and piders They al must be wary of rapacious in ect such as drag r flies mantids phymatid pentatomids a ilid an vespoid Some wasps (Sphecidae) paralyze cater pillars ovipo it in them and place them in pe cially constructed cells Others (I rachonids an ichneumonids) place their eggs in the caterpillar without paralyzing them In either ca e the cater pillars serve as food for the growing wa p larv in ide them Some chalcids ovipo it in the eggs o Lepidoptera

One mite *Myrmonyssus phalaenodectes* Treat in fests the tympanum of a variety of moth and an oth r *Otopheidomenis zalestes* Treat is re tricted as far as is known to the genus *Zale* P eudo cor *pion of the genera Atemnus Stenonithius* an *Apocheridium* have been found on adult of vari ous pecie Lepidoptera are al o subject to viral bacterial protozoan and fungal infection

The Lepidoptera penetrate almo t every corne of the globe with the major exception of Antarc *tica Butterflies of the genus Boloria* have beer taken at Alert on northern Elle mere I land about 400 miles from the North Pole Arctic and alpine tundra areas normally support a lepidopteran fauna which although relatively poor in pecie i rich in numbers After rain de ert are often ali e with butterflie and m th Tropical areas are by far the riche t in pecie One of the strange t habitats oc cupied by a lepid pteran i the hair of the ne trop ical three t ed loth where the sloth moth *Brady podi ola hahneli* Spuler a pyralid pa se its entire life cycle presumably feeding on algae which gr w in the hair The following outline indicate some of the habitats of larval Lepid ptera

1 Plant as ciation terre trial
   a *Feeding expo e l on foliage* flowers or plant lice
   b Feeding on foliage in wel or ca e
   c Leaf and needle mining
   d Living under bark
   e Boring in stem root fruit or ee l
   f In oil fee ling on roots
   g B ring in or fee ling on fungi m e li er wort clul mo es lichen and fern
   h Living in dried plant product such as c re al flour drie l fruit refu e h rl arium peci men

Associat on w th soc l i t
a I beehi e
b I a t t
I i rm te e ts
Associati s th th mals
a I to ed a m l prod t uch a w olens
f th r
b In ha f three-t d loth feeding n algae
In pl t l ce pa to ds
Aqu t c
a Feed n bo ing n o mining in aqu tic
plant
b On rock f d ng m croo gani m

I temper te zones p c es a kn wn which h
mate n every tage f th lif cycle
I dmd al e o l and g graphi riat ns
n nd t k ng the Lep d pt C l r
d sr a ha ter m st f eque tly ffe ted
t gsh p e ti n ge ital a nd ther st u
re lte i l ed The n mber f b d per
n n lte differ geog aph cally

Behav or and physiology M or tion i the m st
tacul r b ha o c ng i th ord It i
nd freq e t i the butte fl *Ph bi D i*
both a d th s b t s l k own i the
ths h s *Ch y d a* Hug m or to v wa ms
re fr que tly rep rt d i m y parts f the w ld
ra this phen m n a well the el t d m
mal roost g of d lt daily e f flyw ys h ll
b pag d of rth s p rly u d t od
Aggr gation f b tte fl at m d puddle e
frequent sight and m ths h e been ob erved
pump g n act h ch t f s pp g w te
mall f om a p ddl nd eje t g t s t m
of dr ps fi p v f om the an
I th fi ld f l p d pt n phys logy the w rk
of C M Will m a d h s s ate g wth d
t mt i h rm n s i la ge atu ni d a d that
of D E Be k on l rv l utr t d b ha o n
P vas bilalis h ld be me t o ed Al o t
w h a e th in e t gat f A T eat d oth
n f th f t n *of the tymp num* e p iaily n
re ert n th th a)et u p e theory that t
m P marily a w rn g m cha m by det t
g th ult son p lse f appr ch g bats
Evolution and genetics Th e i no k ow ex
ant f m ly n th o de N B T d l fam ly
Lowed b sed n *E s t as a* f om the T s
f i t l o g n lly plac d i the Lep
a b t i po t n i ry d btful The r
ber fos l Lep d pt ra a m l p d pt a f m
l T ri ry but it eem l k ly that the r
e ted ll b k in the Meso c perh p fi st
u g n the Ju c
The phen m a f m m cry and p t ct e re m
idesp d in the Lep d pt r
A Blest 19 7 dem t ted th t ey pot p t
m rert pec es l t esc pe re p ses i
wd b d Th s they e n eff ti e p ot
Lep d eter h d ant g f ma y ki d f
meetug i n espec lly f th t dy f

populat n genet J Ge ould first demonstrated a sex limited cha cter n hi wo k on *Colias* E B Fo d C L Rem gt and thers h e been con t ibuti g to g netic with studie of various butte fl es and moth

The ppearance of dark form f arious m ths i hea ly industrial ed a d th s hea ly so ted a eas a w despre d phen me on Th s i dus t l m lani m i doubtl ss d to h fti g sele ti n pre ure and is one of the best k ow exam pl of olut n i ctio *See* ARTHROPODA EVOLUTION ORGANIC GENETICS INSECT PHYSIOLOGY INSECTA PROTECTIVE COLORATION SEXUAL DIMORPHISM [P R E]

Bibl o phy J V B owe Experim tal stud e f mim cry n some No th Ame i n b tt rflie *Ev olutio* 12 32–47 123–136 273–285 1958 C T Br es A L Melander d F M C pe ter *Clas sifi ti of I sect* 2d ed Museum C mp Zo l Bull 108 1954 P R Eh l ch The te me tal at my of the mona ch butterfly *D aus plexip p* L. *U i Kan as S B ll* 38 (pt 2) 1315–1349 1958 P R Eh l ch The mp rat e mor phol gy phyl geny nd h gher cla ficat on of the b tterfl es *U v Kan s S Bull* 39 305–370 1958 E B F rd *B tte fli* 1945 E B F rd *Moths* 1955 A B Klot *Th W ld of B tterfl es and M ths* 1958

Lepidosauria

A bcl s of the R pt l a l pid au are d p d r pt le ch a t iz d by tw tempo l f nestra In the ad an d type e th r one or both temp al ar hes may be lost Th teeth we pr mit ely s b th do t (ket) d bec m a odo t (f ed to edge of jaw) o ple odo t (f ed to s de f j w) Th ert br e we e p im ti ly am ph el (con e t b th end) d b came pr coelo (ca in f ont co ex behind) The lep d sa a r g fr m L te P rm to Rece t the nly l f m *Sph d n* (der Rhyn ch ephal) d m mb s f the d Squam t

Order Eosuchia Th e ch a w e pr m ti l rdlik te rest l d amph b o s form w th typ al d ap d kull a d s bth c dont t eth Th gro p em r l ted t thecodo t b t the d ta ar in deq ate They ar known la gely fr m S th Af c n P mi f s ls Eosu h a l ed d ng M ddl P rmian t E e e t m Exampl s ar *You g a* nd *Ch mp osa us* S THECODONTIA

Order Rhynchocephalia The hy cho eph li n or be k h d w e l za dl ke diap id r pt le with a od nt teeth a d mphi o lo rt b ae The pr maxill ry bo e typ lly w s b klike Rhyn ch ephal n li ed n t r tr l hab tat except for few ma e f rms f ert affin ty They ol ed fr m E s hi n th E ly Tri s i a d fl u sh d b efly th ugh t the w ld i th T i s s Membe of th g p rvi t d y w th l t tle ch ng i the m d rn T at ra or *Sph n do p tat m* of New Z aland Exampl re *Hom s u us* nd *Sph odo* S RHYNCHOCEPHALIA

Table 2 Important Injurious Lepidoptera (cont)

N m	Dam g l y l va
Olethreutidae	
Codl g moth *C p ap pom n ll*	La bo es n pples and som ther fru ts m st mpo tant pest of apples
O ı tal p h motl *Laspevr a m l l*	Feed o f its an l tw gs of p ch s plum et
Tortric dae	
Spru b dwo m *Cho-ı lon r f m f an*	Defol at r of v st a eas of co fe ou f est
Ugly e t to t d l f oll rs t *Ca oec* spp *T l ız* spp	F ed on l a es nd f ts of ppl nd other f ts t w be y h de t ees o n mental pla ts tc
Pyral dae	
O ı t l r bo *Chil n ple*	Very d tr t e to r ce n As a
B m tl G ll a *m ll n ll*	Dest oys mbs n eglected beeh e
I l n me l m th *Plod a ınt p l ll*	W desp l nd ry por tant pest of d ed f t a d m l p oducts ımported f m Eu op
M d t e n flou moth *Eph l k hn lla*	Inf st flou to ed gr c e l
C p le f f ld *D m fu l s*	Som t mes n mpo t t d f l at of g ı s
Geometridae	
Sp g ca k wo m *P l l r t* f ll k w m *Alsophıl p m ta*	D f l t f t nd h d t ees o tb k ye rs ı g a k worm o w nt rs p p f ll c k rw rm a gg
Sph ngidae	
Tom to ho nw rm *Phl g th l us q q ma l l s* t l acco ho w m *P s xtus*	La g l r e most con p cu pests of t m to nd t b o al f d o th sol n eo s pl ts
Lasiocamp dae	
T t cat p ll rs *M l c m* pp	S r d fol ators of f t, h de n l o ch d t
Arct dae	
F ll webw m *Hyph nt ıa n*	F d w d a ty f f est, sh de n l f t tr es
Lymant ı dae	
E rope n gyp y m th *P th l ı dıspa*	Impo t t def l t f f t h l nd fru t t es N w Engl n l
B own t l motl *Nygm ph eor hoe*	S m l r to gypsy m th
Noctuidae	
C tw rms, *E ıroa* pp *P ıdroma* spp t	N n pec s dam g m ny rop pl nt
Arn y w m *Le un puncl l*	V ıes t m d u ly ı l d nce ı eı d m y rs t does g t l m g to co n a l oth g sses
Co n earw m cotto bollworm tom to f tw rm t ba co bu lw rm *H l oth s m g a*	F ceed gly mpo t nt cosmo-pol t n pest tt k g m y cult ted pl ts
P eridae	
C bb g butt fl es, *Pı ıı* pp espec lly *P rapa* U ted St tes	Pests f v r lt ted cruc f rs
Alf lf b tt fly *Col s rvth me*	Import nt pest f lf lf ı so thwest n U ted States

lycaenid *Strymon melinus* Hubner has at time been an important pest of hops

BIOLOGICAL ASPECTS OF LEPIDOPTERA

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   e Boring in stem root fruit or ee ls
   f In oil feeding on roots
   g Boring in or feeding on fungi m es li er w rt club mo e lichen and fern
   h Li ing in dried plant prod ıct uch a cere al fl ur dried fruit refu e herl arium speci men

A soc at o th soc l i sect
I beeh es
b l ant nest
c l term te n ts
Assoc t th other a m l
I t ed animal prod t s h a wool ns f ath
b l ha f three-t ed loth feed ng on algae
c l pl t lic a pa s ito d
Aq t c
a. Feed o bo g i o min ng n aquatic pla t
b On rock feed ng on m croorga ms

Ia t mp te zo es pec e r known wh ch h em te me e y t ge f the l fe cy l I di dual a l and geog ph c tatt ns mm and trik g in th Lepid ptera Col d e a ch ra te m t freq e tl affected t g h p enat n g tal a a d the t s es a e often i l ed Th n mber f b ood per eason ften d ff rs ge g ph call

Behav or and physiology M gr t on s the most pectacul b h i occ rr ng i the ord It m t l equ nt i the b tt fl es *Pho b s D n Libyth a* a d ther b t s l o k wn n the m th h s *Chrys r d* H g migr t ry warm e l equ ntly rep rted m y part f the w ld but th ph me o a w ll a the rel t d c m mun l oo ti g f d alt d lv f flyway hill t pp g d s f rth poo ly u de t od

Ag reg t n f butte fl t m d p ddle are a frequ t ht d moth h e been ob rved p mp g a t wh h n t of p ng w t r t d ly f om p ddl and ej t g it s a tr am f d p r fi e pray from the an s

I th fi ld f l p d pt n phy l gy the w k of C M W ll m d h c te n g owth nd d ff ent t n h rm es i l g tu n d nd th t f D E Beck l rv l utr t on and b h v o n *Py t n b lalis* h uld b m t ed Also n t w rthy a the n t g t s f A T at nd oth rs of th f t n f the tymp um esp lly n co nect w th the a yet p e th ry th t t serves p im rily a w n g mechan m b detect i g th ult p l es f pp o h ng b t

Evolut on and genetics Th no kn wn x t t f mly i th d N B T d l fam ly E set da ba ed *Eo s tri* f m th Tri s of Au t l a wa g n lly pla d n th Lep d pt a b t t po t i rv d btf l The e l est f l Lep d pte a m ol p d pt fr m th ly T rt ry b t t eem l kely th t th r d ted w ll b k th Mes z p h ps fi t d ff nt t ng n th J

Th ph n m f mm ry d p tecti es m bf e w d p ad the Lep d pt a

A Blest 19 7 dem t ated th t eyespot pat t rn rt pec l t e c p respo es p b d Th th y r n effecti pr t c t dev

Lep d pt h d ntages f m ny k nd of r t est g t especi lly f the tud f population genetic J Gerould fir t dem trated a ex limited character in hi work on *C lia* F B Ford C. L. Remingt n and ther ha e b n c n tributing to genetic with studi f ari us l utter fl e and m th

Tl e appearance f d k f rm of variou moth in h ily indu trialized and thu hea ily ooted area a wide pread phenomen n This ind i t al mela m" is d ubtles due to h lting sel t n p ess r and i one f the best known x m ples f e lution in action See ARTHROPODA Ev OLUTIO ORGANIC GENETICS INSECT PHY IOLOGY INSECTA PROTECTIVE COLORATION SEXUAL DIMOR PHISM [P R E]

Bibliog phy J V Brower Exp r mental tudi s *of mimicry* i ome N th Am can b tterfl *Ev* olution 1 3 -4 123-136 273-28 1958 C. T Br es A L Meland a d F M Carp nter *Clas s fi t n f I ts* 2d ed Mu um Comp Zool Bull 108 1954 P R Ehrl ch The tegumental an t my f the monar h b tte fly *Dan us plexip p L*, *Uni K s s Sci Bull* 38 (pt 2) 1315-1349 1958 P R Ehrl h The c mparati e m r ph logy phyl g ny nd higher la fic t f the butt rfli *Uni Kansas Sc Bull* 39 305-370 1958 E. B F d *Butte fl s* 194 E B F rd *M ths* 19 5 A B Kl ts *Th Wo ld f Butte flies* d *M ths* 1958

Lepidosauria

A ub l f the R pt lia lep d a rs are d p id r pt l cha a t r zed by tw t mpor l fe estra In tl e ad c d types e the e r both tempo al r hes may be lo t The teeth were primit ely ub-thecod nt (in ock ts) and became a r d nt (f ed t edge of j w) o pleurod t (fu ed to de of jaw) Th rteb e were p im t ely am ph l u (on a e at b th nd) a d be ame procoel u (c n in f ont c n ex behind) The l p do a a ra ge f om Lat Permi to Recent the ly l g forms e *Sphe odon* (order Rhyn h eph l a) nd memb of th rder Squam t

Order Eosuchia The s chians wer *prim ti e* l za dl k t r t l a d amph b o s f rm w th typ al d ap d k ll a d ubthecod nt te th The gr p ms r lated t the od nts but the data r inad q ate They a e kn wn l rgely from S th Afr an *Perm n lo* l Eo uch ans l v d d r g Middl Perm an t E c ne t me Examples *Y ung a* nd *Ch mpsos u us* See THECO-DO TIA

Order Rhynchocephalia The rhyn hoc ph l ans o b k h ads *we e l za dl ke d ap id* pt l s with acr dont *teeth* nd mphi oel u rtebrae The p m x llary bone typ cally w s be klike Rhyn ho phal *ans l ed t* t rrestri l habitats e cept for a few m n f rms of un e ta ffi ty Th y l ed fr m E hi ns i the Early Tr a i and fl h d b i fly th ughout th w rld n the Tria s M mbe s f the gro p survi e today with l t tl ch g i the mod rn Tu t a r *Sph nodon p t tum* of New Z al nd Examples are *H mo s u us* a d *Sph n d* See RHYNCHOCEPHALIA

Table 2 Important Injurious Lepidoptera (cont)

N me	D m g i y l
Olethreutidae	
Co ll g moth *C poc ps p mo ella*	L bo ppl nd som other fru t m st impo tant pest of pples
O nt l p ch moth *Laspeyr s m l t*	Feeds n f ts l tw gs of p ches plum etc
Tortricidae	
Spruc bu lwo m *Cho- isto ra fum f*	Defol t f t f o f o f est
Ugly t to t d l af ollers tc *Ca oec* pp *T t ix* spp	F d on l l f ts of apples nd oth f ts t w be y sh le t ees o n m nt l pl nt tc
Pyralidae	
Orient l ce bore *Chil mpl x*	Very dest u t to A
Bee m tl *C ll m ll n ll*	D t oy combs in n gl cted l h
I d an m l m th *Plod t p nct ll*	W lesp l l ery mpo tant p t of l l f t d imal p o l t mp te l f o Fu p
Med t ne n fl u motl *Ephest ku hn ll*	I f t *flou t ed g* l
G pe l f f l ler *D sm f al*	Som t m s an i po t t l f l t f g p
Geometridae	
Sp g c k rwo m *P l r t e n t* f ll c nk w m *Alsoph l pom t*	D f l te f t d sh l t tb k y rs sp g k rw m o w ters p p f ll k w m n egg
Sphingidae	
Tom t l w m *Phl g th t q q m c l lus* toba o h w m *P ext*	La g l r most c n sp o pest f tom to l t l cco l o f l o th sol eo pl nts
Lasiocampidae	
T nt t p ll rs *M l m* pp	S o s d f l t f f t h l l o l l tr es
Arctiidae	
F ll w bworm *Hyph t c ne*	Feed on w l ty of f est, sl l d f t tr es
Lymantriidae	
Eu p n gypsy m th *Po th t a d spa*	Impo ta t l f l t f f t l l l f t t ees i N w E gl d
B ow t l m th *Nyg i ph eo hoea*	S m l to gypsy m th
Noctuidae	
Cutw F oa pp *Pe drom pp t*	N m pec es l m g n y crop pl nt
Arm y w m *Le u p t l*	V es t m l ly t l ce p l m y rs t loes g t l m g to corn l th gr sses
Co n rwo m cott bollw m t m t fr tw m t l co b lw rm *H l this m g ra*	I eed gly mpo t t cosmo- pol t n pest tt ki g m y c lt ted pl t
Pieridae	
C l bage l tt fl es, *P r s* pp espec lly *P pa i* U ted St tes	Pests f i lt ted cru f rs
Alf lf l tt fly *Col ryth m*	Impo t t pest f lf lf l so thwest U ited St tes

lycaenid *Strymon melinus* Hubner ha at times been an *important pe t of hops*

BIOLOGICAL ASPECTS OF LEPIDOPTERA

The Lepidoptera are a group of in ects on which much biological re earch remains to be done A great deal is till unknown al out the genetic physiology and ecology of this group Moreover butterflies and moths have proved u eful as experi mental animals in genetical re earch

Ecology and distribution The variation in larval habits is di cu ed under the different familie Lepidoptera of all tage are ubject to the attack of a large number of predator including bird mammals lizard frog and pider They al o mu t be wary of rapacious in ects uch as dragon flie mantids phymatid pentatomid a ilid and vespoid S me wa ps (Sphecidae) paralyze cater pillars oviposit in them and place them in pe cially constructed cell Others (I rachonid and ichneumonids) place their egg in the caterpillar without paralyzing them In either ca e the cater pillars erve as food for the growing wa p larva in ide them Some chalcids ovipo it in the egg of Lepidoptera

One mite *Myrmonyssus phalaenodectes* Treat in *fe ts the tympanum of a variety of moth and an* other *Otophe idomenis alestes* Treat i re tricted as far as is known to the genu *Zale* P eud cor pions of the genera *Itemnus Stenouthius* and *Apocheridium* have l een found on adults of vari ous specie I epidoptera are al o sul ject t viral bacterial prot zoan and fungal infection

The I epidoptera penetrate almo t every c rner of the globe with the major exception of Antarc tica Butterflies of the genu *Bolo ia* have l een taken at Alert on northern Elle mere I land al ut 400 mile from the North I ole Arctic and alpine tundra areas normally upp rt a lepidopteran fauna which alth ugh relati ely p or in pecie i rich in numl er After rain de ert are often alive with l utterflie and m ths Tropi al area are l y far the riche t in pecie One of tl e trange t hal itat oc cupied by a lep id pteran i *tl e hair of the ne trop-* ical three toed l th where the sloth m th *Bra ly podicola hahneli* Spuler a pyralid pa e it entire life cycle pre umal ly feeding on algae which gr w *in the hair* Tl e f llowing outline indicates s me of the habitats of larval Lep id ptera

1 Plant a ociation terre trial
   a Feeding exp e l on foliag flower or plant lice
   b Fee ling on f liage in w l r ca e
   c Leaf an l nee lle mining
   d I i ing under l ark
   e B ring in *tem root fruit or ee l*
   f In oil fee l ng root
   g Boring in or f ling n fu gi mo li er w rt clul m lich n a l f rn
   h Li ing in dri l plant pr l ict h a e re al fl ur dri l fruit refu l rl m m p l men

Leprosy

A chronic infectio d e e of man caused by My cobacte m leprae (H e s bacillus) and oc curring in nodul r (c taneous) and neural form This disease s believed to have originated in cen tral Afric it then pre d t all parts of Europe and subsequ ntly t the rest of the w rld After its introd tion f om the N ar Ea t the d sea e be cam e demic i E rope u til the si tee th ce tury the di appeared It i till widely di emi nated the Orie t. The e are n e timated 3 000 000 l pers in the wo ld—about 450 in th Un ted States d o er 30 000 i Central a d South Amer ic The d se is fo d in the trop c nd b- tropi M l p has not y t been ult ated on b ct l gi l med ti s e c ilt res r experi ental a im ls.

M l p f man d es t prod c pr g es i e infection anim l Rats h e a disea called rat l pr y char cterized by nod lar skin le ions co t ing c d fa t ba ll (M lep mu m) hi h is path g f r ther species d can ot be c lti ted i v t

M l p ppe r n obl g t i tracell lar par t occ rr n large numbe s f globular cl ter (gl bi) in epithel d cell The n d lar aneo and eural ne thetic f rm of the dise se m y oft both occur in the same pat t and e th may h b t lepromatous r t berculo d lesio s. I the od l form th I c tain many b ilh a d th lepr m k n t t (some what anal gou to the tuberculin skin test) is neg ative because the lepromatous tissue is not hyper sensiti e to the products of the bac llus The pa tient e entually dies as a result of complications such as amyloid sis nephritis or tuberculo i

S sceptibility to the d ease is greatest in child hood The ratio between the incidence of the dis ea e n m les and females is approximately 2 1 The incubation period va es from a f w months to many years The d ease is not highly co tag ous and p bably is acquired by infecting superficial abra ons f the skin It is l kely that per on can acq ire the infection with ut de elop g manife t (clini ally recogn ed) d ea e

B cter logic diagnosis is made by find g acid f t ba lli in crap g of the na al mu a or in the t sue fluid e pres ed from certa n reas of the sk Ca ation (death of t ue and tran f rma tion to a chee el k co tency) does n t occur in l pr y De vati es f diam n d phen l ulfone are the drug of ch ce in tr atment *See* BACTERIOLOGY MEDICAL HYPERSENSITIVITY MYCOBACTERIACEAE SKIN TEST [C H M]

Fig. no mol w th l p m t l p y h w g l s ol eo h k o d l d b the het ight h d wh h l h ws m l atrophy d typ l f th th mb (Ph t g ph b H L A ld J)

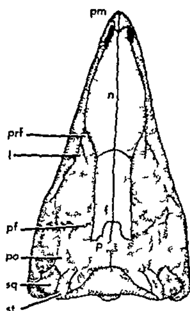
Lepton

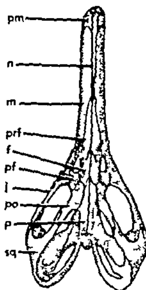
A llecti e ame fo any fermion having a ma small r than the prot n m (a fermion a p rti cl which ob ys Ferm D rac t t ti) The e are s known lept ns the electron (e^-) the μ me n (gati ely h rged mu n μ) and th neut i o ( ) pl thei tiparticle —the p itron (e) th μ me (positi ely charged m o μ) and the ant eut o ( ) Be g fe m ns, the e par t l ha e h lf dd i tegral p in fa t they all h sp ½ħ or ½($h/2\pi$) where h is Planck s co sta t

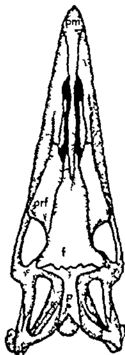
The lepto t ract with lectr m gnetic and gravitational field by irtue of their ch rge and e gy respectively b t beyond thi they a e only known t interact thr ugh the β interactions in th b ad e se These interactions ppear to co erve lept n that i j t as many l ptons c me out of an i t r t as we t n (a t leptons are cou ted gati ely of cou e) Thus e can c nside the lept n to be a single parti l wh ch n exi t in three guise *See* ELEMENTARY PARTICLE [C J C]

Leptospira

A gen f p ch t f the fam ly Spiro h tales M y pec e p duce an ac te d ea in man kn wn W l di As f r m rphol gy b l g har te t and nt gen tru ture re c rned *L ptosp a* ha little i common with eith r the *T p ma* o th *Bo l a g up of* sp ch t The rga m s 4–20 μ in le gth 0 1–0 2 μ w dth a d h s cl ly w u d p ls *L ptosp a* gr w w ll b ally n tifi al med a d the h ck mbry Cl fic t of p th g i p s p m r ly n n t g i b S SPIROCHAETALES WEIL S DISEASE. [T B T]







Lep dosau ian reptiles show ng dorsal view of skulls p pa ietal po postorbital sq squamosal f frontal pf postfrontal prf pref ontal j jugal m max lla n nasal; pm p emaxilla st supratemporal l lacrimal (a) Yo ng na a p im ti e two-arched reptile f om the Upper Pe m an of South Africa length about 2¼ in (afte R Broom D M S Watson and E C Olso) (b) Champsosaurus a Late Cretaceous and early Te tiary amph b ous form length about 13¼ in (aft B Brown) (c) Tylosa rus a mosasaur le gth abou 38 in (after S W W ll ston) (From A S Rome Verteb ate Paleontology Un ers ty of Ch cago 2 ed 1945)

Order Squamata *This order consists of two sub*orders (1) the Lacertilia or lizards (including mosasaurs) which have a single upper temporal fenestra and (2) the Ophidia or snakes which *have lost both temporal arches See* SQUAMATA

Suborder Lacertilia In the lizards the lower jaw is united at mid line the teeth are acrodont to pleurodont and the vertebrae are amphicoelous *(geckos) to procoelous Osteoderms frequently are* present in the skin The group is apparently de rived from rhynchocephalians and includes mod ern lizards (two being poisonous *Heloderma su spectum and H horridum) and extinct marine* mosasaurs (Cretaceous) They range from Juras sic to Recent

Suborder Serpentes (Ophidia) The snakes are *elongate limbless derivatives of monitorlike liz* ards showing adaptation to burrowing swimming or brush dwelling without pectoral or pelvic gir dles except for remnants of the latter in primitive forms *The lower jaw is united by a ligament the* quadrate is movable there is no parietal foramen and vertebrae are numerous and procoelous The teeth are acrodont and recurved The maxillary teeth of several groups *have grooves or enclo ed* channels for poison There are arboreal terre trial aquatic and marine forms They range fr m the Late Cretaceous (*Dinilysia* South Ameri a) to *Recent Included* in the suborder are l id o- lubrid worm snakes vipers pit vipers elapid and ea snakes [B H B]

Lepospondyli

*A term used to characterize amphibian groups i*n which the vertebral centra basically spool haped *are formed by ossification directly around the no*tochord in contrast to the apsidospondylous struc ture seen in the Labyrinthodia where the centra ossify in blocks of cartilage formed well out ide *the notochord* The term Lepospondyli meaning husk vertebra has been variously used some times including only a restricted number of Paleo zoic forms but more recently utilized as a subcla s *name to include all amphibians who e vertebrae* are formed in this general fashion *See* AMPHIBIA FOSSILS

In the Paleozoic the larger amphil ians were *labyrinthodonts but small lepo pondyls appear* to have been very abundant as water dwellers par ticularly in the coal swamp the e f rm are c m monly grouped to form three order the Nectridia *the Aistop da and the Micro auria* The modern orders Ur dela and Ap da have a l a ically lepo spondyl us tructure tl ey are prol al ly de ended from one of tl e P leoz ic lepo pondylou order *(Micro auria) and h nce may l e includ* l in th Lepo p ndyli in a l road sen Exc pt f r th Devonian icl thy tegid the olde t kn wn f il amphil ians are lepo pondyl u an l tl e gr up i thought l y some to ha e be n d ri l in l pen l ntly from fi h anc tor S AISTOPODA GYMNOPHI ONA MICROSAURIA NECTRIDIA [A S R]

lemaeopod d ( ) F m l S lm col thym ll (K ler) (based R G y B d h f h w t C p p d vol. 3 R y S ty 1933) (b) M le S lm l thy mo (K ssl) (fl R G y B f h f h w t C pepod l 3 R y Soc ty 1933) ( ) F -sw m g larva f P l g t (W1) (fl C B Wlso Th p p d f th W d H l g o Massach sett B ll U S N tl M m 158 509–531 1932)

Th free-swimmi g lar qui al t t the fir t copepod te t g eme ge f m the isac E te all t r mbles the hal mus l rva of Cal g d b t intern lly t s n que n h i g p f rmed fro al t be r gi at ng i th f ehead a d t m along n a ll abo e th e phagu The larva robabl f o ly h t p i d must fi d h t ap id. A t bl h t may b y o of pe h p several pec es f fi h th deg ee f h st par te pecifi ty i u lly ot p ced Adher g t ppr p i te t w th hookl ke appe dages th larv m kes und th h t tis the led t.f ev rted and bec mes embedded the ounded a the t su gen t Th t be a tempor m th d f tt hm t dege tes when th l rv m t m rph int th verm f rm r g (Il t t c)

Attachment and nutrition Pe m t att h ment ac mpl hed n tw ways Lernaeop d d e tta hed to th w ll of th fishes gill h mb by tro gl modified sec d ma ll Th e p- pe g es a m l g t d a gel ke appe ance bse g normal egme t t The e d f ed th pex, b tto l k w ll g b ll l bined host ti l Sphyri d the head a d part f th th rax bec m embedded th with i g ll h mb r ext rn lly ft n r th d sal fin. Salm la lm par t zing lm hstand the n d om h b t f ts h t a d k a) xpecta cy of l y l both famil es typ l h ts i cl d h k k te ay and most bo fi hes.

Lernaeopod da appear t f ed n body fl id f the ho t They are n t c n dered a threat t f h popul t on e cept p ll ly nder c nd ti ns f e ce i e crowd g Se COPEPODA [A F]

B bliog phy R Gurney *British Fresh water C pepod* ol 3 R S ciety monograph 1933 C.B Wil n The c pep d f th Wood H le re g on M a hu ett *Bull U.S N tl M u n* 158 509–531 1932

Lespedeza

A warm ea on l g m with t if l ate lea e small pu pl pea hap d l lo oms a d e eed per p d Le pedeza al le to g w n p orer soils th n m t fo ge plant

K n le pedez n early annual spe e is gr w exten ely f m Virg n t Ka K l the c mm r striate annu l spec g wn f th as n rthern Fl r da

B th species are ex lle t f ag a d o l serving pl t Th y re often gr wn with wheat or other m ll gra s by owing 25–30 lb of eed p acre in l te w ter e ly p g After the gr h rv t d th lespedeza plants soon the oil c mpletely f a f ll i ple tiful

L p d (S I C rv t S rv)

Serice th p n al l spedeza omewhat d ffi lt t tabl h Its ed do t germ nat d ly u l s hulled and a fied and th yo g se dl g e not g s the uals It s u lly s wn alo nd th y ung g wth s u ed f g azi g hay

On sandy l t knot n m todes e e i s pe ts of m t l p d as R w o ar et f K ean le p deza i t nt to m t n matodes h w e S LEGUME FORAGES NEMATO A [P T]

Lethal dose 50

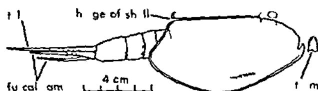
O speci l f rm f the effe t do m d an ff ct e d Th l th l d so r med n l th l d is l o wr tte a LD It is s d wh th p se that i b g n e t g ted th d th f th p me tal m l Th med l thal d e i th f e the d wh ch f tal t 50% f the test m l

The LD_{50} f r t h gi l t e ly to r bbt i 0 5 m ll m p k log m of b dy w ght Th d pt h w th t p fy g the LD_{50} tt ti h bee g e to th pe ie f m l th te f j t d the we ght f th m l ed F th t sub t es a d f f t t f p cifi ti s m ght be imp rt nt

Leptostraca

A small and unimportant group of Cru tacea for merly ranked with the Branchiopoda but now regarded as the most primitive of the Mala o traca Only a few genera like *Aebalia* have urvived to the pre ent time but numerous apparently related Paleozoic fos ils are known

The Lepto traca differ from the re t of the higher Cru tacea the Eumalaco traca chiefly in having an additional abdominal omite which never bears ap pendages a tel on bearing two movably articulated prongs the furcal rami and an adductor mu cle connecting the two halves of the hell or carapace The e are doubtle primitive feature and indicate that the Leptostraca diverged from the main Mala co tracan tock before the emergence of the typical caridoid form The lamellar thoracic limbs are highly specialized not primitive The alliance of the group with the other Malaco traca is amply ju tified by the agreement in number of the append ages by the harp di tinction between the thoracic and abdominal erie and by the po ition of the genital openings They are mo t clo ely related to the My idacea e pecially in their mode of devel opment My ids like *Hemimysis* are now known to have an embryonic caudal furca which is shed at the fir t molt and a eventh abdominal omite which later fu es more or le s completely with the ixth one



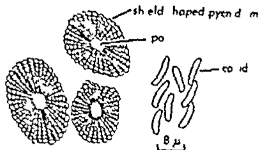
Ce at ca s styg a Salte a fossil leptost acon (Afte T R Jones a d H Woodwa d A Mo g aph of Br t sh Pala o o c Phyllopoda (Phyllocar da Pa kard) Pa la ont graph cal Soc ty)

The fo il Lepto traca are the olde t known Malacostraca ranging from the Cambrian to the Tria ic epoch (ee illu tration) Since they are already well differentiat d in the earlie t f ilifer ou rock they hed no light on the po ible ori gin of the Malaco traca S e MALACO TRACA NE BALIACEA PHYLLOCARIDA [I CO]

Bibliography T R Jone and H Woodward *A Monograph f the British Palaeo ic Phyllopoda (Phyllocarida I acka d)* 1888 1889 V Van Strae len and C Sel mitz, *Crustacea Phyllocarida (= Ar chaeostraca)* Fo ilium Catalogu part 64 1934

Leptostromataceae

A family of fungi of the order Sphaerop idales Although m t specie are apr phyte ome are fruit tree pathogen Pycni lia the fruit b lie on taining conidia are black hield hape l cir ular or oblong an l lightly a mmetrical the open ng of the pycnidium i l ng and litlike There are



Pyc d a and co d a of *Leptothyr m v lgare*

80 genera and 375 pecie recognized Many of the e are conidial stage of Hemi phaeriale (or ler A comycete)

The important genera of the Hyalo porae whose pores are 1-celled and bright (hyaline) are a follow

Leptothyrium with approximately 100 pecie The pycnidium is typically hieldlike *L pomi* cau e apple fly peck

Leptostroma with oblong and thin pycni lia *L pinastri* i a tage of *Lophoderium pinastri* (A comycete)

Melasmia with pycnidia lying in a flattened troma *Melasmia* pecie are imperfect tage of Rhyti ma (Ascomycete)

A representative genus of the Hyalodidymae (pores 2 celled and hyaline) i *Gloeo les* It i imilar to *Leptothyrium* but the pycni lia of *Gloeodes* are gelatinou *G pomigena* cau e ooty blotch of apple *See* FUNGI IMPERFECTI PLANT DI EASE SPHAEROP IDALE [N E B]

Lernaeopodoida

A group of Cru taceans known a the fi h maggot which are ectopara ite partially burie l in the fle h of marine and fre h water fi h They are character ized by (1) a modified po teml ryonic development r du ed to two or tl ree recognizal le tage ( ) a unique free wimming larva and (3) failure when exually mature t how ign of external phy ical maturity t pical of ther opep l The female la king di tin t egmentation and functi nal tho ra ic appendage appear in fi h a c mparati el large w rmlike metime tufted utgrowth Male (illu trati n *b*) are dwarfed and though m re di tinctly egmented d not exceed female m rpl ol gical devel pment U ing modified head ap ndage they cling t th female (illu trati n *a*) l ut retain me free lom f m ement

A a n e quence of R Gurney di cu i n f Lernaeo po l i la in 1933 and C. B Wil n account f the free wimming tage of Spl yriidae in 193 the Lernae p d i la are limited in tl account t th familie Lernaeo po l la an l Sphyrii lae Char a teri tic d ting i l i g tl e e familie are a so iated with the r l rsal l l p nt and special t ti n f r perman nt att l ment to th l ost

Life cycle Tl e inu al l rn eop lid lif cy l l gin with the egg an l eg ing l th embry ni an l *nauplius* (l a of l l pment whil t ta ed in the elongated ternal o ac of the femal

lem opod d ( ) F m l S lm col thym ll (K ler) (based R G y B a h f h w t C p p d vol 3 R y S ty 1933) (b) M l S lm l thy ll (K l) (ft R G y B t h f h w t C pepod l 3 R y S ty 1933) ( ) F w m g larva of P l g t (W l) (ft C B W l Th p p d f th W d H l g Massach sett B ll U.S N tl M m 158 509–531 1932)

Th fr mmi g larv qui al nt t th fi t c pepodite t g me ges f m th visac Exte nall t es mbl the hal mus l rv of Cal go da b t int rnally it un q n h a p f rm d fr tal t be gi at ng i th f eh d a d t m n u g i l bo th e ph gu The larva n st f only ho t p od mu t fi d h t rap idl A it bl ho t m y b y of pe h p ses l pec es f fi h th deg ee f h st p r te specifi ty s u lly n t p n ced Adhe ng t a pp pr at t w th h kl ke app dag th larv mak a w d n th host tis th o led tube i exerted nd bec me embedded n the w ded e th t eg er t s Th t be a t mpor ry m th d f ttachm t dege tes b n th l rv m t m ph es i t th erm f rm stag (ll t at)

Attachment and nutrition P rma ent att h ment is mpl h d tw ways Ler aeop d d e tt hed t th w ll f the fi hes g ll h mb b str ngl mod fied ec d ma ll Th e ap pend ges m a el g t d a g l ke ppear e bec g orm l s gm ntat n The e d f e d th pex, b tt l ke w ll g b ll l es bu ed i h t t e In Sphyr d the he d d p rt f th th b m mbedded the withi th g ll hamb r tern lly ft ea th d sal fin. Salm ncol s lm p t g lm rh t nd th d m habt f it h t d fa a l f pect y f l y l b th fa l es typ l h t l d sh k kat y and most bony fishe

Lernae p do da app ar t feed n b dy fl ids f th ho t They re n t c n d ed a threat to f h p pulat ons e ept p lly u de co d ti n of e e i e rowd g *Se* COPEPODA [A F]

B bl ogr phy R Gurney *Briti h Fresh ater C p poda* l 3 Ray Society m n g aph 1933 C. B Wil n The c p p ds f the Wood H le re g M s hu ett *Bull U.S N tl M seum* 158 509–531 193

Lespedeza

A warm ea on l g m with t ifol ate lea e mall p ple pea hap d blo om d e eed per pod Lespedeza a af le to g w poorer ils th n m o t f age plant

K e n le pede a a early annual pe e is g w exte ely fr m Vi gi a t Kan K b the c mm n r str ate ann l spec s g wn as fa th as northern Fl r d

B th species a e excelle t f g nd il serving pl t Th y fte gr wn with wh at r oth m ll gra s by owing 25–30 lb of eed p acre in late wi ter ly p i g After the g n h rv t d th l p d a pla ts oo r th soil completely f nf ll plentiful

l p d (S l C rvat S rv)

S ce the pe e nial le pedez is omewh t d ffi lt t establi h It eeds do n t germ nat d ly unle h lled nd sca fi d and the you g dlings a ot s igorou the n uals It i ally wn l e d th y ung g wth s u d f grazi g hay

O a dy soil r t k ot n m todes are eri p t f m st le p d s R w n e iety f K l sped e i t t to m st ematode howe e *S* LEGU IE FORAGES NE IATODA [P T]

Lethal dose 50

O e pe l form f the ff ti e do se or med n eff t e d e The lethal d 50 or med n l th l d e l wr tt LD It is ed *whe th* r p that is b g i e t gated th de th f the e p ime tal mal Th med n l th l d the f e th d wh h i f tal to 50% of the test an m l

The LD f r t y h g n s be t ou ly t bbit i 0 5 m ll am pe kil g m f b dy ght Th d pt h w th t n pe fy g the LD tt t h bee g n t th pe e f n m l th r ute f nje t d th we ght f th m l ed F ther t x s b t *n e a d f* f t t f p c fi t n m ght be import t

The use of the concept of LD_{50} is not restricted to toxicology because there are many therapeutic substances such as digitalis which can be assayed more conveniently by their lethal effect than by their therapeutic effect The same active principle is involved in both effect See BIOASSAY EFFECTIVE DOSE 50 TOXICOLOGY [C W H]

Lethal gene

A gene which brings about the death of the organism which carries it either when homozygous (that is a recessive lethal) or when heterozygous (that is a dominant lethal) Lethal genes constitute a very common class of gene changes and are a reflection of the fact that genes control the processes essential to growth and development of organisms Dominant lethal genes are rapidly eliminated but the recessives are retained with considerable frequency in natural populations of cross fertilizing organisms

Many lethal mutations have proved to be losses of small or large sections of chromosomal material rather than gene changes in the strictest sense When lethal mutation or losses occur the effect is expressed as a failure of growth or as an abnormal course of development leading to the death of the organism carrying them Most detectable lethal genes are recessive and are expressed only when homozygous If the processes controlled by a particular gene come early in the developmental sequence the disturbance produced by its loss or mutation is often severe and extensive if the processes occur later in the sequence the disturbance usually has fewer ramification An analysis of the effects of lethal genes provide a valuable mean of investigating the complex processes of embryological and later development and in the case of man has practical medical implications as well In microorganisms the study of lethal biochemical mutants has opened a new era in the unravelling of biosynthetic processes

The following are examples of lethal mutants biochemical lethals in the microorganisms *Neurospora* and *Escherichia* lethal chlorophyll mutants of higher plants Notch and many others in the fruit fly *Drosophila* Creeper in fowl Yellow Brachyury *W* anemia in the mouse gray lethal in the rat Dexter in cattle thalassemia sickle cell anemia and many other in man See GENE ACTION HUMAN GENETICS [D F P]

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Lettuce

A cool season annual (*Lactuca sativa*) of Asian origin and belonging to the plant order Campanulales Lettuce is grown for its succulent leave Four ul pecie of this leading salad crop which are grown are head lettuce (*L sativa* var *capitata*) leaf or curled lettuce (*L sativa* var *crispa*) cos or romaine lettuce (*L sativa* var *longifolia*) and stem or asparagus lettuce (*L sativa* var *asparagina*) There are two types of head lettuce butterhead and crisphead or iceberg

Propagation The outdoor crop is propogated by seed usually planted directly in the field but also occasionally planted in greenhouses for later transplanting Field spacing varies plants are commonly grown 10–16 in apart in 14–20-in rows Greenhouse lettuce predominantly leaf and butterhead varieties is transplanted to ground beds with plant placed 7–12 in apart

Uniformly cool weather promote maximum yield of high quality lettuce 55 65 F is optimum Heading varieties are particularly sensitive to adverse environment High temperatures prevent heading encourage seed stalk development and result in bitter flavor and tip burned leave However varieties vary considerably in their resistance to these high temperature effect and to disease Commercial production of lettuce is extensive in several California and Arizona valley where mild winter and cool summer climate prevail

Crisphead or iceberg lettuce is the most widely grown type strains of the Great Lakes and Imperial varieties account for most of the acreage Popular varieties of other types of head lettuce are butterhead Bibb and White Boston Grand Rapid cos or romaine and White Paris are popular types of leaf lettuce

Harvesting The harvesting of heading varieties begins when the heads have become firm enough to satisfy market demands usually 60 80 days after planting Most western grown lettuce is field packed in paperboard cartons and chilled by vacuum cooling

Leaf lettuce and cos lettuce are harvested when full sized but before the development of seed stalks or a bitter taste This varies from 40– 0 days after planting

California raises more lettuce than any other state Arizona and Texas are next in importance Total annual farm value in the United States is approximately $123 000 000 See CAMPANULALES VEGETABLE GROWING [H J C]

Diseases of lettuce Lettuce diseases of greatest importance are caused by fungi and bacteria which disrupt the structure and function of the invaded parts causing malformation discoloration and breakdown of tissues The injuries produced are usually classified as spots rots scab wilt or blight

The most serious fungus diseases and their causal organism are sclerotinia rot *Sclerotinia sclerotiorum* gray mold rot *Botrytis cinerea* downy mildew *Bremia lactucae* anthracnose *Marssonina panattoniana* and bottom rot *Pellicularia filamentosa* Several fungi of minor importance cause leaf spot

The most serious of the bacteria parasitic on lettuce are *Erwinia carotovora* and *Pseudomonas marginalis* both of which cause soft rot Soft rots are especially damaging when they follow injuries and di a [illegible] spotted wilt and tip burn

( )

(b)

Plate ( ) H d (b) L f (F m L H Ba l y d Th n d rd Cy l pedia f H rt ltu l 2 M m lla 937)

Virus di e es f l tt ce u ually are transmit ed by inse ts th t feed on the plants Big em so ever s believed to be cau ed by a soil borne rus. Othe ir d ea es f mporta ce are mo- saic, v ll and potted wilt

Tp burn, phy log cal di e e i e peci lly damaging to h d l ttu e The exa t cau e of tl s trouble is n t known See PLANT DI EASE PLANT PHYSI LOGY PLANT VIRUS [C B R]

Leucettida

An d f the s bcl Cal nea in the clas Calcar a. These p ge ha e either a r d ate arra ment of the fl gellated chamber leu co d tru t re A d tinct dermal membrane o cortex i p ese t The sp ng c l is not li d with ch anocyt Th ell re re t ict d to the flagel la ed chamb s T fam l s the Leuca c dae a d Leu ft d e ec gn zed *Leuc scus Leuc tt* and *L al is* re ampl s See CALCINEA s e als CALCAREA [W D H]

Leucine

	Physical constants f the omer 25 C
	K (COOH 2.36 pK (H) 9.60
	Isoelectr point 5.98
	Optical rotation [ ] (H O) 1 [ ] (HCl) +1
Leucine	Solubility (00 1 H O)

A amin d id ed es ent al fo norm l growth of anim l Th mino acid are ch act ized ph lly by th foll w g (1) the pK he d soc t n o t nt f the i us t trat bl groups (2) th soelect c p t, pH at whi h a d pol i doe not migr te i a lect ic field (3) the pt cal r t t n, or the rotati n imp ted to beam l plane-p l ized l ght (f eq e tly th D lin f the od m spe trum) p ng th o gh l decimeter f a sol t n f 100 gr m in 100 ml (4) sol b ty *Se* EQUILIBRIUM IONIC I OELEC TRIC POI T OPTICAL ACTIVITY SPECTROPHOTOMET RIC AN LYSIS.

In l uci bi synthe is carboxyl and s m c r bon at m of le a e d ed from acetat the rest of the molecul is furn hed by α ketoisovale te wh ch ari es in the biosynth is of aline A con densation of ac tyl enzyme A (acetyl CoA) with α ket so lerat followed by es of react ons an log us to th tri bo yl c acid cycle has been prop d (b t n t demonstr ted) to expl n the f rm t on of α ket oc p ic acid Th compo nd is known to y ld leucine by tr n aminat on (se AMINO ACIDS TRANSAMINATION)

Du ing metab lic deg adati the first steps are deamination and idati deca boxyl t on form ing i v lerylcoenzym A (iso aleryl CoA) The foll wi g seque e t kes pl c

CH – CH – CH – C – – Co ⟶ CH – C=CH – C – S – Co ⟶ (Senecioyl)

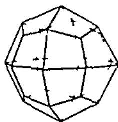
CH – C – CH – C – – Co ⟶(CO₂) HOOC – CH – C – CH – C – S – CoA ⟶ (β Hydroxy β-meth lg taryl Co)

[E A AD]

Leucite

A rock f rm g m al bel nging t the feldspath o d group L u te u ually ccu s i d t nct crys- t ls f metri t p h d l f rm At o di ary temp t es thes ry tal do n t h a i o- m tr c st t re b t ar ggr g tes of cry tals of l we ymm try p b bly tet go al If heated to 500– 00 C, they b om truly sometr c with the tru t r conforming t th m rph logy Th com p s ti n KAlS O b t me d um may sub ti t t f p t si m Th h d es 5.5–6 on M h sc l and the sp fi g av ty i 2 45–2 50 The c l whit nd th lu ter t eo t dull See FELDSPATHO D

Le t c u ly in gn u r cks that are low n il u u lly n Re nt l flows The embedd d crystals may c t n cl si ns of mag



Leucite showing trapezohedral hab t of crystal (*From C S H lbut Jr ed Da a s Manual of M neralogy 16th ed W ley 1952*)

netite and other minerals arranged radially or in a concentric manner Its most noted occurrence is in the rocks of central Italy particularly as pheno crysts in the lavas of Vesuvius In the United States it is found in the Leucite Hills Wyoming and in the Highwood and Bear Paw Mountains Montana I seudoleucite a mixture of nepheline analcime and orthoclase is found in pseudomorphs after leucite *See* LEUCITE ROCK PHENOCRYST

[C S HU]

Leucite rock

Igenous rocks rich in leucite but lacking or poor in alkali feldspar Tho e types with essential alkali feldspar are cla ed as phonolites feldspathoidal syenite and feldspathoidal monzonite The group includes an extremely wide assortment both chem ically and mineralogically

The rocks are generally dark colored and apha nitic (not visibly crystalline) types of volcanic ori gin They consist principally of pyroxene and leu cite and may or may not contain calcic plagioclase or olivine Types with plagiocla e in exce s of 10% are called leucite ba anite (if oli ine is pre ent) and leucite tephrite (if olivine is absent) Types *with 10% or less plagiocla e are called leucitite* (if olivine is ab ent) and oli ine leucitite or leu cite basalt (if olivine is present)

The texture is usually porphyritic with large crystals (*phenocry ts) of augite and leucite in a* very fine grained or partly gla sy matrix If plagio cla e occurs as phenocry t it is generally lal ra dorite or bytownite and i lightly more calcic than that of the rock matrix It may be zoned with m re calcic core urrounded by more sodic margin I eucite appear in two generati ns As large phe nocry ts it forms slightly rounded to octagonal haped grains with abundant tiny inclu ion of gla or other minerals zonally arranged Small round grain of leucite with tiny gla inclu ion al o occur in the rock matrix Augite or diop ide (ometimes rimmed with aegirine augite) and aegirine augite form the mafic phenocry t Pyrox ene of the matrix i commonly oda rich Oli ine *may* occur a well formed phenocry t Other min erals pre ent may include nepheline odalite l i tite hornl lende and melilite Acce ori incl id sphene magnetite ilmenite apatite and perov kite

Leucite rocks are rare They occur principally as lava flows and mall intru i es (dike an l l canic plugs) Well kno n are the leucite ro the Roman province in Italy and the ea t c African province In the Italian area the feld oidal lavas are e *entially leucite ba alt* an have developed by differentiation of ba alt m (rock melt) In the African province the le rocks are as ociated with ultramafic (perid rocks and may have been derived from peri material Thi may have been accompli hed l abstraction of early formed cry tal from a pe tic magma or by the mobilization of perid titic by emanations from depth A imilati n of stone by ba altic magma may help to decrea silica content and promote the formation of le in tead of potash feldspar The cry tallizati leucite however is in large part a functi n of perature and water content of the magma C tions of formation therefore may trongly *ence the formation of leucitic rock See* IGN ROCKS NEPHELINE SYENITE PETROGRAPHIC I INCE PHONOLITE [C A

Leucosolenida

An order of the subcla s Calcaronea in the Calcarea The e sponges have an a conoid s ture A true dermal meml rane or cortex d e develop in this order and the pongocoel i l with choanocytes One family the Leuco oleni is recognized *Leucosolenia* and *Ascyssa* are e ples of this order *See* CALCAREA *see also* CARONEA [W D

Leukemia

A disea e of mammals characterized by a ma increa e in the number of white cell (leuk cy in the circulating blood An increa ed numl e circulating white cells (leukocytosis) i foun *many di ea e proce e e pecially infecti n* in the e the increa e ul ide when the underly disease proce s sub ide and repre ent a reac of the l ody t the infection pro e In leuke on the other hand *the leuk cyt is per i t* progre e independently of any ol vi u cau e the conditi n i eventually fatal D ring tl e c of the di ea e the white cell are di tril through ut the l ody and eventually *infiltrate m* organ

Normal white cell are pr duced in the l marrow of tl e healthy in li i lual a are th cell (erythrocyt) of tl e irculating l l l In leukemic patient the l ne marr w i the chief of pr ducti n of tl numer i irc ilating wh cell Leuk mia may n ni ntly l e regar led a form of canc r of tl e l n marr w in l ing l ukocyte pr lucing ti ii An anal g i di in l ing tl e red c ll pr l i ing ti i f tl m row i kn wn a pol yil mia era In tl i n ti n there i ac l rat f r f i ti f r l ll c ll marke lly i cr a ing tl r n ml r in tl c ilating l l l (Fig l) S HEMATOI II I

Classification Th le ik mi ar i ially la fied ac ordi g t tw f t r On tl f i f lir ti n f th illn fr m n t t d atl l k m

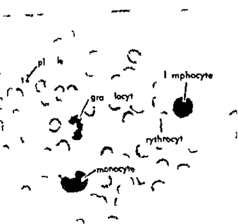


Fig 1 N rm l to ed bl od m h w g g ocyte ly phocyte m ocyt d cl mp of pl t l t

m y be c t w th a total co se of less th a year r hr ni la ting more than a y ar Acute and chr c l ukem a may lso be cla s fied ac co d g t th type of ell l ed In g anulocyt c (also alled m eloge us) le kemia (Fig 2*a*) the p ed m ting cell e embles the gr nulocyte r pol m ph lear l ukocyt f the n rmal blood S arly lymphocytic (o lymphat c) leukem a (F g 2*b*) h ra t rized by a cell corresp d g to th n rm l lymphocyte and th les common monocytı l kem (F g 2*c*) by ll rresp d ing to th m ocyte The diff nt leukemias vary th n d ces d l nical m nifestations

Dur g th c r e f devel pme t f whit ell in th bon ma r w the app ara f the cell hanges Th yo ngest fo m f a h var ety of hit cell esemble the p im rd l t m cell wh ch by conti mit t d ı n b me the p r nt f all blood c ll As th ell mat e ı th m w t y gr d lly tak n the pp nc f the ma tur e l t g ells and fi lly e r l d nto the blood Cha a t tic lly c t le kem a (Fig 2*d*) th ı l ed cell f l t mat e d are leased ı t th blood at an early t ge f the d l pm t Th th ll fo d ı th ul ting blood are morpholog ally ımmat re In chr nic leuk mia mo t of the ell reach a c ideral le degree f maturity b f re they ar rel ed al tl ugh ome y ıng f rm are always present In tudy g a g n c of l kem ıt ıs p ible to pred t whether ıt w ll f ll w an acute r a ch nic co rse by aluat g the degree of mat rity f the cells ın tl e cı c l ting blood

G locyt c leukemia ın ol es th granul cytes or p lym rphonucle r ell wl ich a the cell tl at by their capacity t ınge t nd destr y l ct ıa are o ımp rtant ın the defe e of the l dy agaın t ınf ction Lymphocyte which ar ın ol ed ın the ther common f m of leuk mia h e a poo ly unde t od fu t on N m lly m t of them re n t f rmed n the m rrow but ı mall o ga catte ed through t the body known lymph n des Howe they are n rmally pre ent n mar w and ı lymphocytic leukem a th marrow ıs o e r with them n all t g s of devel pme t The uncomm n monocyt c l ukemia ınv l es th monocyt a motile ph gocytic cell that ı clo el related or ıde t al to the m rophage r wander ıng ll found ın ll tı ue of tl e body M cyt leukemia lly follows a acute r subac t c u

A g up f dı ea es cl ly r l ted t th l u k mı are the lymph mas The e are a neoplast c ınv l eme t f the cells f the lymph n d d ften of the m rr w without relea e of the pro- l fe t g cells ı t the l t g blood The tum r ppe to remain l calized for a co s d bl period f t me b t t ally l es many g f the body Some f rm f lymph ma diff f m h lymphy ytic leukemia only n the bsence of the h te tic c ll f m the periph ral blood In fact ı l e of lymph ma will h ge to d nary lymphatic leuk mia b el g t ell ı to the blood Neopl stic p o- life t n f th gr locytı ell f the m row with t l m t f the ul t ng bl od e rare The e m t m d g ated by the p a doxic l te m l k m l kem They ften represent h t ph (d na y l kem and usu lly foll w th s m c e *Se* Blood

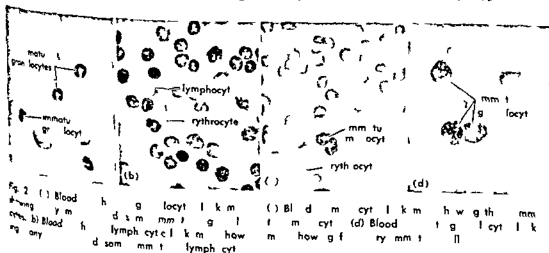
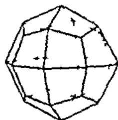


Fig 2 ( ) Blood h g locyt l k m ( ) Bl d m cyt l k m h w g th mm showing y m d s m mm t g l t m cyt (d) Blood t g l cyt l k cytes b) Blood h lymph cyt c l k m how m how g f ry mm t ll ng any d som mm t lymph cyt



Leuc te show ng trapezohed al hab t of crystal (F om C S Hu lbut J ed Dana s Manual of M eralogy 16th ed Wiley 1952)

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[C S HU]

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Leucit rock ar rare Th y occur principally ... fl w and small intru i es (d k and v l canic plugs) Well kn wn are the leucite rock the R man pr vince in Italy and the ea t-ce African province In the Italian area the feld p oidal lavas are es entially leucite ba alt an l have developed by differentiati n of ba alt ma (rock melt) In the African province the leu rocks are associated with ultramafic (perido rocks and may have l een derived fr m peridc material Thi may have been accompli hed b y al straction of early formed cry tal fr m a peri tic magma or by the m bilizati n of peridotitic r b y emanations from depth A imilation of l stone b y ba altic magma may help to decrea e silica content and pr mote the f rmati n of l u in tead of potash feld par Th cry tallization leucite however is in large part a function of t perature and water content of the magma Co tions of formation therefore may str ngly i ence the formation of leucitic rock See IGNE ROCKS NEPHELINE SYENITE PETROGRAPHIC PR INCE PHONOLITE [CA

Leucosolenida

An order of the subclass Calcaronea in the cl Calcarea The e sponges have an a conoid st ture A tru dermal m mbrane or c rtex doe develop in this order and the spongocoel i li with choan ocytes One family the Leucosol nii is rec gnized *L ucosolenia* and *Ascyssa* are ex ples of this order *Se* CALCAREA *see also* C CARONEA [W D

Leukemia

A di a e of mammal charact riz d b y a ma increa e in th number of white c ll (leukocyt in th circulating blood An increa d numb r circulating white cells (leukocyt is) is f und many di ea pro e e e p ially inf ti n l in the e the in rea e ul i f wh n the und rl i di ase pro e s sul ide and repre nt a rea ti of th body to th e inf cti s proce In leuk m on th ther han l the l uko yt i p r i t a pr gre e and p nd ntly of any b i us an e a th n liti n i e ntually fatal During th c ur of th li a the whit ll ar di trib it through ut th body an l ev ntually infiltrate ma organ

N rmal wh it ll are pr lu l in th b marrow of th h althy in livi l ual a are th re c ll (erythrocytes) of th irc ilating bl od In th l ukemi patient th bon marr w i th ... f productio n of th num r i circulating whi cell Leukemia may c n en ntly b r gar l l a form of can r of th b n r arr w in lving th leuk ocyte pr lucing ti ues An nal g i li a ins lving th re l c ll pr lu ing ti i ... r w i kn wn a p ly yth mia r In th ... tion th r i ac l rated pr l ti n f r l bl c ll mark lly in ea i g th ir number in th ul ting bl ood (Fig 1) S ... HEMATOPOIE ...

Classification Th l uk mia are t ially la i fi d ac r l ng t tw f t r On th b a ... l ira ti n f th illn fr m n et t l ath l uk mi

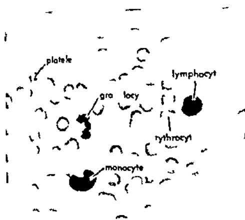


Fig. 1 N rm l to ed blood m h w g g locyte ly phocyte m cyt d cl mp f pl t l t

ma be ac te, w th a total cour e of l than a year chr lasti g m e th a yea Acut and chr n l k m m y al o be l fied ac co ding t th type f ell n ol ed In g a ul cyt c (lso alled myel ge) l k m (Fig 2*a*) th p ed ting cell resembles the g a ulocyte or polym rph cl le kocyte of the norm l blood im larly lymph yti (or lymph t) l kemia (Fg 2*b*) h racter ed by ll c p d g to th n rm l lymphocyte a d the le s comm n monocyti l k m a (F g 2c) by a cell corr pond ng to th m ocyte Th d ffe ent le kem ry their n d es d lin l ma fest t s

During th *cou se f dev* lopm t of wh te cell th bon m rr w th ppe nce of th ll changes The y gest f rms f ea h etv f white ell *esemble* the p mord al t m ell wh ch by co t u mitot c d o b m the pare t f all blood c ll As th c lls m tur n the marr w they grad lly t ke th app r e f th m tu l t c lls a d finally a e ele ed t th bl od Ch acter tic lly n a te l k m (F g 2*d*) th l *ed ell fail* t m t d le sed nt th bl od at a a ly stag f the r d l pme t Thu th ll f d n the c r l t g blood are morpl logic lly immatu e In hron c leuk mia mo t f the cells r a h a on deral le degree of matu ity bef re th y are relea ed al though me y ung f rms a alw y p e t In study g a g n ca f le k mia it p ble t pred t whether it w ll foll w an acute or a hronic c r e by e alu t g the d gree f maturity of tl e cells n the ci culating bl d

Gra ulocyt c leukemia invol e the g an locyte p lym rph nucle ells wh l are tl e cell th t by their apacity t ingest nd destr y bacteria a e so important i the def e of the body aga n t i fection Lymphocyte wl ich a e i l ed in tl e other mmon f m of leukem ha e a poorly und t od funct on Normally mo t f them are n t formed n the ma r w b t in m ll rgan scatte ed thr ugh ut th body kn w a lymph n des Howe r they are n rm lly pr ent in mar row and i lymph cyt c le kemia the m w i o err with them n all stages f devel pm nt The unc mm monocyt c le kemia in ol es the m ocyte a motile ph g cyti cell that is cl ely related d nt al to the m c oph ge r w d r i g ll found in ll t es f th body Monocytic leukemi lly follows an acute or ubacute r e

A g up f d ea es closely related to the l kemi a e the lymph m Th are a ne pl stic l m t f the cells of the lymph nodes a d often of the m r w w tho t r lea e f th pro l fe t ng cells int the c culating blood The t m ppe t rem i localized f r c n ider able period f t me but e tu lly n ol es m ny g f the body Some forms of lymph m differ f m h lymphy yti l kem only the ab e ce f the h t t ells f om tl pe iph eral blood In fact n occa al ca f lymph ma w ll h ng to o di ary l mphat leukem by el ng ts ll int th bl od Ne pl t c pro l f t f th g an l yt cells of the ma ow w th t l em t f th i culat ng blo d ar ar Th y e m t mes de g ated by the par d c l term le kemic le kem " They often rep e ent but pha e f di a y le kemia and lly f ll w the me cours *See* BLOOD

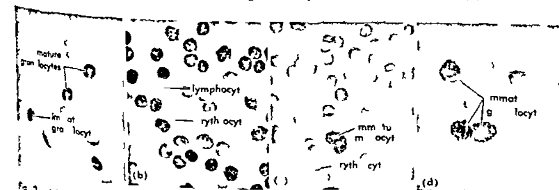


Fig 2 (a) Blood h g l cyt l k m show g y t d m mm t g f cytes b Blood h lymph cyt l k m h w ng many atu d som mm t lymph cyt ( ) Bl d m cyt l k m how g th mma t m cyt (d) Bl d t g l cyt l k m h w g t ry mm t ll

Incidence and epidemiology Leukemia has been observed repeatedly in a number of species of domestic animals notably in horses cattle and dogs Occasional cases have been reported in swine cats goats and rabbits as well as in a few wild animals including elephants and monkeys Leukemia is recognized in rats mice and guinea pigs and these common laboratory animals serve as convenient subjects for the experimental study of the disease It would seem that with sufficient observation leukemia would become established as an important disease of all mammals A leukemia like disease transmitted by an infectious agent occurs in a number of avian species Little is known about leukemia in reptiles amphibians fish or the invertebrates

In man the age incidence varies with the particular type of leukemia The acute leukemias occur chiefly in children and young adults though no age is immune Chronic granulocytic leukemia becomes increasingly common after the age of 25 and is prevalent at all older ages Chronic lymphocytic leukemia is unusual before the age of 45 and after 50 its incidence rises rapidly paralleling the incidence of the common malignant diseases Monocytic leukemia is usually seen in middle aged persons (Fig 3)

The leukemias are about equally common in both sexes except for the chronic lymphocytic variety which is three times as common in men as in women

Human leukemia is prevalent in all parts of the world but it seems to be more common in countries that have a higher standard of living and are technologically more advanced Part of the difference may be due to more efficient diagnosis and more accurate reporting in these countries although in the United States leukemia is less common in Negroes than in other races

Leukemia is becoming more common In nearly all countries where reliable statistics are available there has been a steady rise in the incidence of leukemia which has about doubled itself in the past 20 year Improved diagnostic methods and better reporting are not enough to account for this rise Indeed leukemia is increasing as a cause of death more rapidly than any other disease except cancer of the lung and coronary thrombosis

The cause of the increase is still unknown Increasing use of x rays in medical diagnosis may play a part but cannot account for the whole picture

Physicians constitute the only occupational group with increased incidence of leukemia They have about twice as much leukemia as the general population and radiologists who are exposed to small doses of radiation in their daily work have ten times as much as other physicians

Survivors of the nuclear bomb explosions in Hiroshima and Nagasaki in 1945 have a definitely higher incidence than nonexposed Japanese Patients given large doses of x rays in the treatment of ankylosing spondylitis a nonmalignant condition affecting young men are found to have a s[ignif]icantly increased incidence of leukemia many [years] after the exposure The above three as oc[c]a[sions] are the best evidence for the hypothe[sis] that [ion]izing radiation can cause leukemia in man Th[ere is] at present no concrete evidence to suggest other specific factors what they may be is stil[l a sub]ject for speculation

Leukemia is not a familial disease in the [ordi]nary sense it is not inherited Indeed a nu[mber] of leukemic mothers have been delivered of he[althy] infants However there is a slight familial tend[ency] toward leukemia patients with leukemia are [more] likely than other patients to have leukemic [rela]tives

Etiology Generally speaking the problem o[f the] cause of naturally occurring leukemia is not so[lved] However some agents are known that can c[ause] leukemia in some species including man

Many attempts have been made to identif[y an] infectious agent of leukemia These have been [suc]cessful only in birds The prevalent and econ[omi]cally important disease of domestic chicken[s, a] leukemia like condition known as fowl leukosi[s, is] caused by a virus The disease is evidently i[nfec]tious in nature and can be transmitted experi[men]tally from an affected animal to another in the [lab]oratory It is not necessary to use living leuk[emic] cells to transmit the disease tissue extracts pa[ssed] through filters fine enough to remove all an[imal] cells and even bacteria are sufficient The filter[able] agent or virus of fowl leukosis can be cultiv[ated] in vitro under very special conditions It will [not] grow in embryonated hen s eggs like so many c[om]mon viruses but will grow in tissue cultures of c[ells] of the natural host Further the virus appear[s to] impart neoplastic properties to these cell even [in] vitro

Since 1951 several investigators have been a[ble] to transmit mouse leukemia by means of cell [free] filtrates prepared from tissues of afflicted anim[als] Only newborn mice seem to be susceptible to [the] filterable agent and there is a considerable ti[me] lag before the subject develops clinical evidence [of] the disease Not all the treated animals deve[lop] leukemia It would appear that a filterable age[nt] probably a virus plays a key role in mouse l[eu]kemia but it is probably not the only factor [in]volved There is no evidence that leukemia can [be] transmitted in man although transfusions of l[eu]kemic blood have been given to nonleukemic p[er]sons

Leukemia occurs spontaneously in many strai[ns] of mice and it has a very high incidence in so[me] highly inbred strains suggesting that at least [in] this species hereditary factors play a role Ho[w]ever it is also possible that strictly hereditary fa[c]tors are not responsible but rather that the filte[r]able virus suggested above is transmitted fro[m] generation to generation by way of the ovum Le[u]kemia can be induced in mice of a susceptib[le] strain as well as in other species of laboratory an[i]mals by exposure to ionizing radiation Sever

chemical gents, includ ng methylcholanthrene in crease th in dence of l uk mi in colonies of s- eptible strains of mice Some naturally occur r g hormo es ha e a simila effect when given n large doses e a co s de able pe iod of time

In man, n relation bet en the ecog ized hor mo es and le kem a is known H wever me e perime ter ha e been able to isolate from the urin of leukemic pati nt sub tan es that produce overgrowth f the bone marrow when injected into guinea p gs. The ub tanc i olated f om patie ts with chro ic gran locytic leukem a bri gs about hyperpla. a of the granulocytic cells f the m r

hile th ub tan e i lated f m human ca s lym hocyti leuk mia nduces hyperplasia of the lymphocyti c ll Th o g n of these substances within the body is u know The re ult of these expen e ts h e ugge ted t the n e tig to s that certain f rm f h m leukemi may be due to overproduction of ne tl e tl e of both of these h rmo l k sub ta ce But as y t there is no real sati fa tory ev d n e to implic te these bsta es in the etiology of le kem a.

Th re is n co v c ng p oof th t any f the above agents, th th x ept on f i n zing radia tion, pl ys a r l in the a ation f human leu kemia. It is p ob bly best t rega d human leu kem a a a neoplasm a form f can e aff cting th cell f the blood th bone m rrow and the lymph od Th cau f nce i howev r u known, nd t classify l kem a a cancer is not t answ th quest on f its au t n r doe it imply th t le k mi has the same t logy o a similar o as any th r form f c n er It m st not, t e ampl cl se out mi d to the po sib l ty of irus infecti everal i t ertible ancers f e m mmalia spe es udo btedly h e a vir leu l gy

It seems likely th t number of fa tors m t cooperat t p oduce le k m a man Pe hap a susceptibl h ed tary o titution is ne e ary upon which one or several external agents must a t to produce the disea e *See* HORMONE ONCOLOGY VIRUS X RAY(S) PHYSICAL NATURE OF

Pathology and pathogenesis If leukemia is re ga ded as a form of cancer the pr mary site of the neoplast c prol fe ation i the bone marrow or the lymph node in the ca of lymphocytic leuk mia No mal blood formi g marrow i about ne half fat and the r m inder on i t of *multiplyi g and* d el ping precur rs f th blood cells red cells white cells and platelets *The p n pal functi of* the red cell i t *carry oxygen to arious part of* the body *The white cells f ari s kind play a* key part *in the ti ie re ponse known a* inflam mat on and are import nt i the d fen e of the body again t infect on l y mic o gan ms The pl telets ha e an import nt fun ti n in blood coag lat n They plug mall break in the wall of blood ve.sels a d p omote the format n f clots With ut them small wound may bleed unc ntr llably for long p riod

Hype pla a Und r rio co d ti ns the bo e marr w elements may und rg hyperpla a r ve growth In ac te anemia from sudden l s of blood th red cell p ecu sors m ltiply rapidly a d their number in the marr w i crea e notably new ma t e ed ll are thrown t into th cir ulati g bl od pla ng the defi it in sh rter t me th n w uld be po ible with ut hyp rpl s S m larly in acut infect ns whe g a ulocytic white c lls re mo g nt the ite of fect n fr m the bl od the prec rso of the white ells i the m r row nderg hyperplasi nd pour their m t re ff p ng int the blood These f ms f hyperpla ia ha e a usef l fun t on nd e importa t n re- t ring the body qu l b um fter it h been d tu bed a n the example abo by h morrhage o asi by bact ia When the u d rlying c e f the hype plasia no l nge pe at wh n the a em repl ced o the inf ction ed the mar w ret rn t it orig n l co d ti

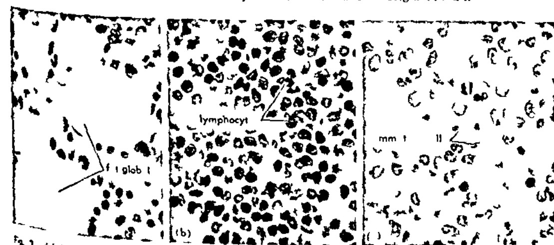


Fig 3 ( ) N rm l bon m row ct h w g variety f c ll nd gl b l f f t (bl k p) 3 Bon m rr w i h o lymph cytic l k mi + wing ost mpl te pl c m t by lymphocyt ( ) B m w t g o l cyt l k m h w g ly mpl t pl m t by ry imm tu e ll

Leucocyte proliferation In leukemia however the hyperplasia of white cell precursors in the mar row differs from physiological reactive hyperplasia by being relentlessly progressive and apparently uncontrolled It is autonomous and is not depend ent on any recognized condition of the rest of the body As the primitive white cells multiply they first replace the fatty tissue of the marrow After a time they replace all of the available fat and pro liferating further begin to crowd out the progeni tors of the red cells and of the platelets Micro copic examination of the marrow shows massively increased numbers of immature white cells at the expen e of red cell and platelet precur ors In ome cases especially of acute leukemia the overgrowth of white cells is so ma sive as to impinge upon and de troy the hard calcified tructural tissue of bone producing areas of bone erosion visible in x ray film occasionally painful tumors and rarely frac ture

While the leukemia cells are proliferating in the marrow many of them are being relea ed into the blood Normal blood contains 5 000–10 000 white cells per cubic millimeter in man (somewhat more in most dome tic animals) in chronic leukemias counts of 100 000 are common and counts of more than 1 000 000 have been reported In acute leu kemias the white cell counts are not so high but in the e the cells fail to mature and are relea ed into the blood at an early stage of de el pment In chronic leukemias on the other hand many of the cells released into the blood are fully mature some are of an intermediate stage of de elopment and only rarely are very young forms found

From the circulating blood the leukemic cells colonize the various organs of the body The liver (Fig 4*a*) and spleen are involved early in mo t cases and these organs soon become diffu ely in filtrated with huge numbers of leukemic cells The spleen especially in chronic granulocytic leukemia becomes tremendously enlarged The kidneys (Fig 4*b*) lungs heart skin lymph node and other organs often become infiltrated The leukemic cells continue to proliferate in the e new locations pour ing more cells into the circulating blood As they multiply they lead to enlargement of the invol ed organ and to eventual impairment of its function Generally the increased number of circulating white cells produces few disturbances in the well being of the patient and it is not until late in the course of the chronic form of the di ease that the viscera become sufficiently involved to destroy their function At this time infiltration of the liver may lead to jaundice

Complications due to anemia Anemia is a fre quent complication of leukemia and occurs early in the acute forms As the leukemic cell crowd out the red cell progenitors in the marrow red cell production is impaired Another mechanism also contributes significantly to the anemia The spleen which normally destroys and disposes of red cells at the end of their useful lifespan in becoming in volved with leukemia becomes excessively active and de troys red cells at a faster than normal leading to a condition known as hemolytic ane

Purpura Similarly the leukemic proce s ch out platelet formation in the marrow leadin decreased circulating platelets and con eq bleeding tendency or purpura Bleeding is u u not an early manifestation in chronic leuken but is often an initial symptom in the acute fo The l leeding tendency may be manifested by bruising small hemorrhages in the skin and muc meml ranes or by serious hemorrhage from bowel or lung Paradoxically platelets are so times increased in the early stages of chr granulocytic leukemia

Resistance to infection As the white cell a role in resistance to infection it might be s posed that leukemic patients would be at least mally resistant However these patients suffer f more than their share of infectious proces es appears that the neoplastic wildly growing often immature white cells are not nearly o cient in coping with bacteria as their normal c ins In acute leukemias especially the very yo cells in the circulating blood are ineffectual recognized infections probably contribute to fever that is so often pre ent in acute leuken Severe destructive infections about the mouth prone to occur in acute cases

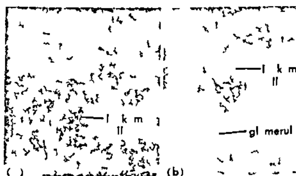


Fig 4 (a) L ch o c g anul cyt c leukem show g i f ltrat on by le k m c cell (small da k cell (b) K dney in ch o c granulocyt c l kem a sh wi f lt at o by leukem c lls (sm ll da k cell)

Terminally there develops the picture of c chexia the marked weakness and wasting een the late stages of most malignant diseases All t patient s metabolic resources seem to be diverted supplying the leukemic proce s at the expense the normal vegetati e processes of his body *Se* CIRCULATION DI ORDERS LEUKOPENIA

Course and treatment By definition chron leukemias have a course of more than 1 year fro onset Most cases havi g mature cell in the bloo survive a good deal longer Granul cytic leukemia average about 3 year and lymphocytic leukemia somewhat longer But the outlook for survi al variable and cannot be predicted accurately in an given case Occasional ca es of chronic lymphocyti leukemia ha e been kn wn to survi e in relatively good general health for 10 or more years Othe

es m su mb t a compl cat n early i the co rse f the di ea e

Pat ts th acute l k m are u ally q te ill from th t. d lly the r ill e p g es rap dl and r l tles ly to a fatal o t m Oc ca l po t r m o s cur especially in ch ld en and all evide ce f d ea e may d s appe f a pe od f m ths during wh h the pa n t seem e t elv well In t bl howe the process a becomes a t e and the p tient s cumb t ac te l kem a

At th prese t t m le kemia is i riably f tal d p te a a labl t eatment How a gr at deal an be d ne t keep the huma p t ent fe ling ll d n g m t f h i lne In som ki ds f l ke a, l fec und btedly be p l ged

Th e are th ba c ki d f t tm t in c r ent u (1) r d t n (2) d ugs that i t fere with c ll l m lt pl c t n and (3) t d hor es

X r k ll l i g c lls d h e the pr perty f affecting a t ly gr wi g a d pr life ting cell lo d g level th th y affe t mat re ad lt cells Thu r di ti s lect ly k ll m ny leu kem c ll b f re m t of th th body c ll are gh fi tl i jured H we e e n mall d es of rad t n nj e th n nl uk mi cells of th ma th h g c ll of th bo l a d the g rmi l tr f the g ad all ap dly m lt ply g lls Suffi ient d g of ad at to kill all the le kem c ll c ot be g e w th ut dest yi g other t ues d d ge u ally l m ted by the d g d e t n rm l bo e ma row ll with t h the i d d l w uld d f em h m th ge o fect n R d at on n be admi ter d ther xternally by me of an x ray mach ne or int rn lly by gi g th p t nt r d ct o tope Phosph rus-32 i ally u ed Thi el me t accumul tes le t ely n th r p dly gr w ng ell f the bo e marr w wh r its sh rt ra g beta radi i att ks m ny c ll a d pa e m h f the est f the body Rad to i u el s a d d n ger in ute l k mias

In ecent y r everal dr g ha e b en de el oped h h m m x ay n the l ct destruc tio f a t ly pr l fe at g cells They t by int f r g w th e rt i b s hem al p es es necessary f r ll c ll growth a d ell d io Some f these drug an be u ed i a te le k mi s h oc i lly th y prod c a c mpl t m s- on la t g sev ral month ev n a y r o m r s o d h rm nes r pre ented by co tiso nd a m be l d t helpf l th sympto- mat c trol of e l f rms f leukem In c te leukem f child en they oc a n lly du e d, m t r m i n Th m h n m f a t n f these h rm es in l kemi i t k wn at th p esent tim

[P B H]

B bl g phy W A D Ande s n P th l gy 3d d 19 7 W D m hek a d F Gunz, L uk mia 19 9 C C d Gru hy Cl c l H m tol gy i W d al P t 1958 M M W t b Cl c l H matol gy 4th ed 1956

Leukocidin

A s bstance th t de tr ys leuk cytes the white cells f blood Leuk cid s are xt acellular b- tance which appear i the en nment f certain pecies of gr wi g bacter a They are relea ed into culture media a d th r physical and hemical p pertie gge t that th y e proteins

Leuk d n ca l e detected by a variety f method f example by impairment of capacity of le kocyte to reduce methyle e bl e r other hydrog n acc pt rs reduct n or lo s of loc mo- t n of leuko yt s alte atio in cellular m rph l ogy a revealed by e minat n f l ing c lls r tai ed pr parations r lea e f ly zyme r other enzymes by damag d leukocytes a d fa lu e f l kocytes to ggl t te in the pre nce of ka l n and lkal The mo t th ro ghly t died leuk cidi s are tho e p odu ed by taphylococci nd trepto- cci I mo t inst nce the r ole in tl e ge esis of d ea ha ot been clearly e t bl hed *Se* STAPHYLOCOCCUS STREPTOCOCCUS [A W B]

B bliog phy G P Glad t ne nd W E van Hey ge St phyl coce l le cocidin *B t J Exptl P thol* 38 123–137 1957 E W Todd The leu id n of gr up A h m lytic treptococci *B it J Exptl Path l* ol 23 136–145 1942

Leukopenia

The co d ti of the blood ch ra terized by a de rease n the n mb of cir lat ng white ell or le kocyte It s n t a di e in itself but rather a ymptom It may occ i the co se of a gr at ri ty f d eas Its impo tan e n any g en a e d pend o its ev ity nd o the nat r of the derlyi g path log c proce I s m condi t n le k p nia may be i id ntal conc mi ta t in others t m y be the ut ta ding feat e d t ll a io th eat t lif

The l uk yt pl y n essent al role i the body mech ni m f d fe e ag nst nf ct o by m ny k nd f mi roorg m A m rked d c e e th n mber f ail ble white ll weake s th d fe e nd t i the th e t of unc tr ll ble n fect n th t on tit tes the men ce of leukope i

The rm l wh t c ll o t i m n ranges be- tw 5000 a d 10 000 ll per cubi millim te f blood Co ts betwee 2000 a d 5000 e c m mo a n mber of o dit o and may n t be f g e t g fic ce h wever u ts b l w 2000 are f g a e impo t Of th th e k nds of wh te c lls f d n rm l blood th gra ulo ytes the lym pho ytes d the mo o yt s it the gr n l cytes that r l g ly ffected n m st f rms of leuko- p n d th e ell r the m st importa t n es t n e t i fect n *S* BLOOD INFECTION

Etiology and pathogenesis Leukop n a oc u s s n c d nt l find ng in a a t d h ter geneo gro p f p th l g c nd t Amo g these i fe t l d g th f b cter al v r l a d pr t zoal g f x mpl typh d feve i fl za a d m l a Howe r in m st f the om m n ba te al i fect n th wh t c unt le

Leucocyte proliferation In leukemia however the hyperplasia of white cell precursors in the mar row differs from physiological reactive hyperplasia by being relentlessly progressive and apparently uncontrolled It is autonomous and is not depend ent on any recognized condition of the rest of the body As the primitive white cell multiply they first replace the fatty ti ue of the marrow After a time they replace all of the available fat and pro liferating further begin to crowd out the progeni tors of the red cells and of the platelets Micro scopic examination of the marrow shows ma sively increa ed numbers of immature white cells at the expense of red cell and platelet precursors In some cases especially of acute leukemia the overgrowth of white cells is o massive as to impinge upon and destroy the hard calcified structural tissue of bone producing areas of bone erosion vi ible in x ray films occasionally painful tumors and rarely frac ture

While the leukemia cells are proliferating in the marrow many of them are being released into the blood Normal l lood contains 5 000–10 000 white cells per cubic millimeter in man (omewhat more in most domestic animals) in chronic leukemias counts of 100 000 are common and counts of more than 1 000 000 have been reported In acute leu kemias the white cell ounts are not o high but in the e the cells fail to mature and are released into the blood at an early stage of development In chronic leukemias on the other hand many of the cells released into th blood are fully mature some are of an intermediate stage of development and only rarely are very young forms found

From the circulating blood the leukemic cells colonize the various organs of the body The liver (Fig 4a) and sp leen are invol ed early in most case and these organs oon become diffu ely in filtrated with huge numbers of leukemic cells The spleen especially in chronic granulocytic leukemia becomes tremendously enlarged The kidney (Fig 4b) lungs heart skin lymph nodes and other organs often become infiltrated The leukemic cells continue to proliferate in these new location pour ing more cells into the circulating blood As they multiply they lead to enlargement of the invol ed organ and to e entual impairment of its fun tion Generally th increased number of circulating white cells produces few disturbances in the well being of th patient and it is not until late in the course of the chronic form of the di ease that the viscera become sufficiently involved to destroy their function At this tim infiltration of the liver may lead to jaundice

Complications due to anemia Anemia is a fre quent complication of leukemia and occurs early in the acute forms As the leukemic cells crowd out the red cell progenitors in the marro red cell production is impaired Another mechanism also contribute significantly to the anemia The pleen which normally destroys and di po es of red cells at the end of their useful lifespan in becoming in volved with leukemia becomes excessively active and de troys red cells at a faster than normal rate leading to a condition known as hemolytic anemia

Purpura Similarly the leukemic proce s chokes out platelet formation in the marrow leading to decreased circulating platelets and con equent bleeding tendency or purpura Bleeding is usually not an early manifestation in chronic leukemia but is often an initial symptom in the acute f rms The bleeding tendency may be manifested by easy bruising small hemorrhage in the skin and mucous membranes or l y serious hemorrhage from the l owel or lung Paradoxically platelets are some times increased in the early tages of chronic granulocytic leukemia

Resistance to infection As the white cells play a role in resistance to infection it might be up po ed that leukemic patients would be at least nor mally resi tant However the e patients uffer from more than their share of infectious proces es It appears that the neoplastic wildly growing and often immature white cells are not nearly o effi cient in coping with bacteria as their normal cou ins In acute leukemias especially the very young cells in the circulating blood are ineffectual Un recognized infections probably contribute to the fever that is so often present in acute leukemia Severe destructive infections about the mouth are prone to occur in acute cases

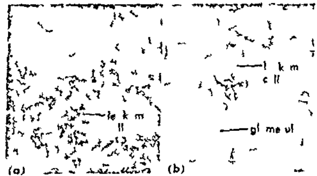


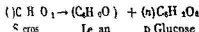
Fig 4 (a) Li e i ch onic granulocyt c l kemia sh wi g nfil at on by leukem c cells (small da k cells) (b) K d ey n chro c g anulocyt c leukem a showi g nfil at on by le kemic cells (sm ll dark cell)

Terminally there develops the picture of ca chexia the marked weakness and wasting een in the late tages of most malignant di ease All the patient s metabolic re ources seem to be di erted to supplying the leukemic pro es at the expense of the normal vegetative proce se of his b dy *See* CIRCULATION DISORDERS LEUKOPENIA

Course and treatment By definition chroni leukemias have a cour e of more than 1 year from on et Mo t ca es having mature cell in the blood survi e a good deal longer Granul cytic leukemias average about 3 year and lymphocytic leukemias somewhat longer But the utlook for survi al is variable and cannot be predicted acc rately in any given case Occasional case of chronic lymphocyti leukemia have been known to survi e in relati ely good general health for 10 or more years Other

lth gh the m lecular s ze f the polysaccharides formed b diff r t m croorgan ms varies it is al ways h gh, being of the rde of 10 or more The levan are polyfructo e cha ns having u its mutu ally j ined th o gh c b n at m 2 (glycosidal h droxyl) and carb n atom 6 p siti ns therel y diff n g fr m inulin, which ha its D fruct se u its jo ed thro gh c rbo atom 2 nd carb n at m 1 po tio

The microorgan ms e suc ose as a ubstrate b t pol me ize only the fructose molecule to form th levan



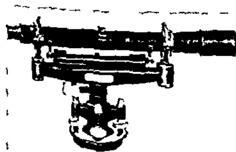
$(\ )C\ H\ O_1 \rightarrow (C_6H\ _0O\ )\ +(n)C_6H\ _2O_6$

S cros Le an D Glucose

S Polysaccharide. [W.Z H]

Level (surveying)

An instrument f establ shing a horizontal l ne of ght The level u lly co sist f a telescope and atta hed pir t l el, mo ted n t pod f r r ta tion abo t ertic l x The lin of s ght i fi ed by oss h rs Stad a hai s may be p o ided fo use in c n keepin f re ht and b ck ight ep l. The t b l pirit l el i l is long and it uppe interior surf ce s grou d to c rcul r arc At t th c ter of the gr und at is paral lel th the lin of ght thu the lin f ght i h zontal wh th sp t le l bubble i cente ed The in trument s level d by ma ipulati n f fo t screw n the m u t ng



Engineer wy l vel

Engineer le l in lud the dumpy w th telescope rigidly att hed t the upp rt g y ke and the wye, w th th tel sc pe remo able f om the y ke. A p ec e le l ha a la lev l f approxim t l li g nd a m cr m ter s rew f final centering f th tubul l v l b bble Th b bble can be viewed thr gh a eries f p i m wh le the rod i ad

A d li t p c ple s appl ed in self l el ng instruments. Th mag fy ng opt al yst m fo e ubl h g the l ne of ght u pended w th n a hou ing by fine w es. Alt p elim a y leveling with footse a d c ula le el th l n of sight em ns h rizontal f all p int ng Fo th les is n urvey g se Surveyi g

[R H DO]

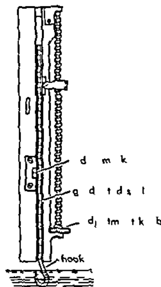
Level measurement

The dete min ti n of the line r ert cal distance between a ref rence po nt and the su face of a l quid r the top of a pile of di ided olids Since there i little imilar ty between liquid and olid level measureme t they are t eated eparately in th s article

LIQUID-LEVEL MEASUREMENT

S ti f ct ry meas rem nts a po sible only when the liquid is ndistu bed by turbulence w e a ti n When a liqu d is too turbulent for the a erag l el to be r ad a baffl or stilling chamb r i i erted in the tank or v s el to pro ide a at sfactory su face

Stick hook and tape gages The e are u ed in open es el wh re the urfa e of the liquid c n eadily be observed Th stick gag i a suitably divided verti al rod or ti k ncho ed in the ve sel



Fg 1 H k g g (F om W U w A T I *Hyd l M m ll* 1912)

th t the m gn t d of the i e d f ll f the level may b mea ured The hook gage (F g 1) p o ides a eedle po nt, which is adj t d to d sturb the l q d u face sl ghtly at the l el read g the eby min m zi g the me us rr r Th t pe g ge e ds th co rect l el when th l qu d j t to ches the po t f th pl mb b b (F g 2) In e mportant r t n f th tape gag th comple ti n f n lect c rcuit thr h th tape pl mb bob nd l qu d detert th cont ct f th b b w th the l qu d u f e nd lmn t s the n d fo r c e i l bservat n of the liqu d f

Gage glasses Ma y form of g ge gl s r a l ble f the mea m nt of l q d lev l Liq d in a tank es l i onne ted t the gag gl by u tabl fitt ng and when th t nk i unde p e the ppe end f the gl s mu t b on nected t th ta k p pa Th th l quid ses t bstant ally the ame he ght in th glas

vated reflecting the increased production of white cells by the marrow and their transport to the involved tissues But even these infections if overwhelming may be associated with leukopenia if the demand for white cells is o great that the resources of the marrow are exhausted

Leukopenia is regularly found in a group of di eases whose only common factor is enlargement of the spleen as for example cirrhosis of the liver The mechanism of this form of leukopenia is not entirely understood Some investigators postulate a hormonelike substance produced in increased amounts by an enlarged spleen that specifically inhibits development of leukocytes in the marrow Attempts to i olate and identify this hormone have not been successful

Advanced and widespread cancer may produce leukopenia when it invades the bone marrow extensively and effectively crowds out the white cell producing ti sues In thi condition known as myelophthi is there is an associated anemia due to the same cause

Leukopenia sometimes severe and life threatening is regularly produced by certain physical and chemical agents when they are given in sufficient dosage Among these are x ray benzene arsenic and a group of synthetic compounds used in the treatment of leukemia These agents all have the power of selectively injuring rapidly dividing and proliferating cells They thus impair multiplication of the white cell precursors in the marrow which are among the most actively dividing cells in the body Accidental exposure to sufficient dosage of radiation—as from the products of nuclear weapons or of benzene which may occur in industrial exposure—may result in a severe progressive and fatal leukopenia Smaller doses produce a milder leukopenia or none at all The drugs used in the treatm nt of leukemia and other neoplastic di eases are given in dosages carefully controlled to keep the bone marrow depression within tolerable limits However the leukopenia induced by therapy occasionally becomes a clinical problem

Another chemically and pharmacologically diverse group of drugs many of them in common use rarely or occasionally produce a severe leukopenia in especially sensitive patients although they have no effect on the white cells of the great majority of the patients who receive them Amidopyrine is a well known offender and several sulfonamides antihistamines anticonvulsant agents and a variety of others are occa ionally implicated The mechani m whereby these drugs can produce such devastating effects in an occasional patient while having no effect on the majority even when given in large doses is not known There is some evidence that it is a hypersensitivity phenomenon related to allergy The leukopenia usually appears after the drug has been given for some considerable period of time or often during a second course of treatment with the same drug suggesting that sensitivity is acquired in the manner of an allergy

A considerable number of cases of evere leuko

ble cause and are designated as being idiopathic See ALLERGY ATOPIC LYMPHATIC SYSTEM X RAY(S) PHYSICAL NATURE OF

Course and manifestations The milder incidental forms of leukopenia usually produce no clinical manifestations and will not be discussed further The more severe forms as produced by radiation or chemical agents often pre ent the clinical pictures of pancytopenia or agranulocytosis

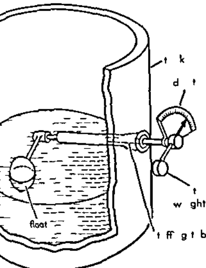
In pancytopenia all circulating blood cells red and white as well as platelets are diminished reflecting depressed production of all of these elements by the marrow This condition can be produced both by the regular marrow depressing agents and those producing hypersensitivity as well as occurring spontaneously The clinical findings are those of an aplastic anemia leukopenia and purpura a bleeding tendency due to diminished platelets Often anemia is the most serious problem requiring repeated transfusion but in other cases repeated and poorly resisted infections due to the leukopenia predominate The cases induced by drugs frequently recover after a variable period of time if the patient does not succumb to infection early in the course but many of those occurring without known cause follow a chronic course for many years Microscopic examination of the marrow in pancytopenia may show either hypoplasia with generally reduced numbers of the precursors of the blood cells or a normal degree of cellularity with failure of the young cells to mature

Agranulocytosis is the name applied to the acute illness resulting from drug hypersensitivity or occasionally from an undiscoverable cause It is manifested by a rather sudden onset of severe leukopenia often with complete disappearance of the granulocytes There is usually no associated anemia or platelet deficiency Most of the symptoms and the high mortality are due to infection by bacteria The clinical onset is often sudden with chills fever marked prostration soon followed by evidence of infection which often takes the form of ulcerati e lesions in the mouth The patient may die in a few days of pneumonia or dissemination of the infectious process throughout the body With modern antimicrobial treatment infection may be controlled for a time but even so the condition has a high mortality Bone marrow findings are variable and nonspecific but there is always a lack of the more mature white cell precursors

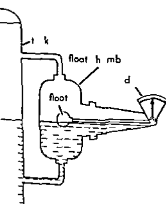
The only treatment that is undoubtedly useful is the administration of antibiotic drugs to control infection These drugs have been life saving in some cases but their effecti eness is hampered by the almost complete lack of the patient s natural mechanisms of defense See CIRCULATION DISORDERS [F B H]

Levan

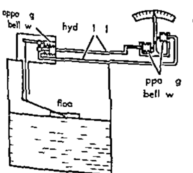
A polysaccharide and a polymer of D fructose (fructans) produced by a range of microorgani ms such as *Bacillus mesentericus* *B vulgatus* *B subtilis* *B megatherium* and *A robact r levanicum*



Float-o d l m h m



E t m l fl t-a d l m h m



Float-ope t d hyd l l l g g (D M ne d P ss l st m l d C t l H d McG -H ll 1957)

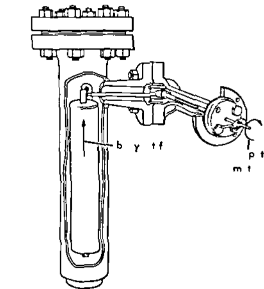
rr s l g eate m gn t de th n with the mech n m B oy t yl de or d pl r prim importa c f ppl c t n l ed und r pr e. As the le l h g s th r a f e devel ped w th t a pp ec movem t f th d pl r Th f t n tted th o gh th es el wall by a haft d qu tube flex bl t b r fle ble d

phragm Becau e mechanical frict n is mi im zed d placer units a e sensit e to sm ller ch nge in le el th n float units which require tuffing boxes Anoth ad a t ge that l g di placer can be pp rted o short le e a m becau e of the n glig ble tra el with level chang th good de gns can be p id d f r larger le el cha ge than can be rea o ably handled by the fl t and le er sy tem

Displacer type l l element are a ailable in m y de igns for b th the int rnal nd e tern l tank installati n I Fig 9 the small m t n f th d splacer i b o ht t of the ta k f meas uring or tr nsm io purpo es by sm ll shaft w thi a t que t l e which supp ts the d pla e I Fig 10 the cha ge in weight f the di place s d tected ext nally by a nozzle and baffle and is balanced by a p eum ti erv

Pressure gages Hydro tat c h d may lso be u ed t me ur liq d le el The head f a liq d v ies dire tly w th ts de ity as well as with its lev l and thu this meth d of me sur ment r qui es th t den ty b sub tant ally co sta t De siti s f l quids a y w th tempe at e ro are there f re ntroduced w th t mpe at e hanges or the m sur ng elem nt mu t be temper tu e mpen sated Err are al i t od ced if appre iable fl w o ur in the l ne lead g t th he d me s u i g el me t

Mo t pressure me ing el m ts may be u ed n l quid le l i The p e r gage is l mited to el tiv ly l ge le el ha ge i pe t nks Mer ury a d a o d m nom t r a b u ed fo nt med at ra ge in cl ed well s pe tank b ca e the nst um nt e b i lly d ff e ti l p su m as ing de i s The bell m n meter and sl ck d ph agm gage a b adapted t the m a eme t f sm ll l qu d le el ch ng F d t l n p es e mea ur ng de i s e PRESSURE MEASUREMENT



Fg 9 T q e-t b l l t (F h G C)

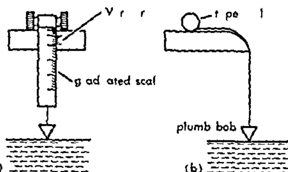


Fig 2 Tape gage (a) Front view (b) Side view

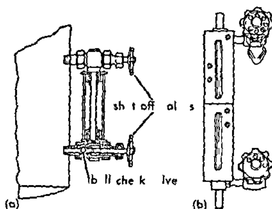


Fig 3 Gage glasses (a) Low pressure type (b) High pressure type (From D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

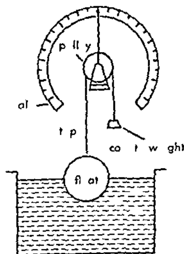


Fig 4 Float tape and pulley gage (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

as in the tank and this height is measured by suitable scale In order to avoid errors due to capillarity gage glasses with an internal diameter smaller than ½ in are not recommended unless a correction is applied Most gage glasses are equipped with shut off valves to permit cleaning and replacement of the gage glass without emptying the tank and with check valves to prevent loss of liquid in the event of glass breakage Low pressure gages are cylindrical glass or plastic tubes high pressure gages are metal tubes with thick glass windows (Fig 3)

Float mechanisms Various types of float mechanism are also used for liquid level measurement. The float tape and pulley gage provides an excellent method of measuring large changes in level with accuracy (Fig 4) It has the advantage that the scale can be placed for convenient reading at any point within a reasonable distance of the tank or vessel It can be applied to the measurement of liquid in tanks under pressure but frictional errors are introduced in bringing the tape through the wall of the tank One solution is to maintain the tank pressure over the entire length of the tape and read the tape through a glass Another solution is to introduce a magnetic coupling between the float which is under pressure and the tape actuator which is at atmospheric pressure (Fig 5)

Float and lever mechanisms These may be used advantageously in closed tanks under pressure when the liquid measured is viscous or when it would foul a gage glass The internal type is located directly within the tank and is connected to an external indicator through a stuffing box (Fig 6) The external type incorporates an auxiliary cage or housing with connections to the liquid and vapor space in the main tank (Fig 7)

Float operated hydraulic level gage This utilizes the float and lever principle to actuate a remote gage through a hydraulic coupling (Fig 8) Float movements transfer liquid between a transmitting bellows and a remote bellows in the receiving gage A dual opposed hydraulic system permits the mechanism to operate under pressure and compensates for temperature changes in the connecting hydraulic lines

Buoyant displacer elements The change in buoyancy of a solid as its immersion in a liquid is varied is used to measure liquid level This principle is used for liquid level measurement only when the densities of the liquid and vapor are substantially constant Temperature changes will pro-

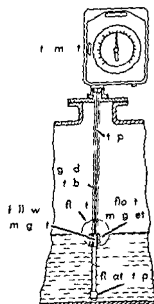


Fig 5 Magnetic type float gage (Fischer and Porter Co)

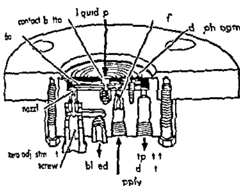


Fig 14. F rce-bal n d ph agm-typ le l t a s- itter (T yl f st f C)

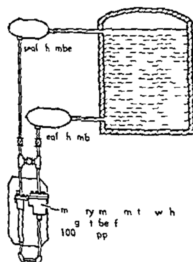


Fig. 15 Me ury m m te w th l q d al tank (T yl l stru t Co)

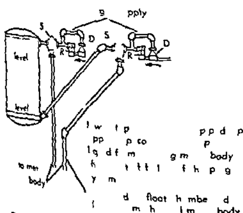


Fig. 16 Gas-p ge y tem f l l m u m t in dosed ta k D d ff t l p g l t ro e with dl l a d S l a ed ea ch be q d (F om D M. C d d Proc s I str m t nd C t l H db k M G w H ll 1957)

the purge gas flow The bottom edge of the dip tube or box is de gned to nimim ze the size of the bubble relea ed

When the liquid being measured is h ghly cor ros e or conta ns solid particle and the gas purge is not sat sfactory a liquid purge a c mbi at on ga and l qu d p rg or a combinati n air and team purge is p s ibl

The pre ure l ead f a liquid above a reference po nt may al o be mea ured by a force-balance diaphragm v t m As the l el varie the dia phragm operates a en itive detector s ch as a nozzle and baffl and a s mple servo to produce a f r e equ l to that de el ped by the l qu d head (Fig 14) The diaphragm is ma ntained n a sub t ntially consta t p siti n Th impl t y tems are pn umatically ope ated and the pre ure op po ing the l q id head s equal to it Other system pp the hydro tat c h ad on the diaphragm with p e s r n a bell ws of reduced are o that the p e u e change f r a g en level ha g i magn f ed Th fo ce-balance d aphragm y tem el m n tes the pu g y tem and its ma ntenance p ob l m

Clos d t ks When ma meters other d ffer ent al pres ure elem nt are appl ed to level meas r ment i l d ta k a ec nd onne tion mu t be m de to th tank at a high r le el (Fig 15) N rmally the d tan e b tw en th tw ta k c n necti ns s qual t th c l b ted range of the man m te d id d by the d ffe nce b tween the d ty f th l qu d and th ap r in th tank The xt rn l leg is filled w th liquid to e l ch m ber at th upp r c nn cti n in the t rk to a id th un ert nty d e t o den at on nd p sible o e fl w into an u filled leg Thu er pres ure occ r when th liq d n the tank s at the upp r level a d th m x mum p e s re i read wh n the l q id n the tank t the l w r conne tion r the ef r n e l el To a oid onfus on i th erv c th ma met al br ted n r e s that it r ad z r when the tank liqu d s t th r fe en e le l Tempe ature change on th xt rnal leg au e re d ng err r nd t r al leg ha e been u d t oid th t o ble The d fferent al p e u e m a u i g elem nt may be r m tely loc ted f om the tank so that l ad l ne err r a a o d d

G s-p rge y tem (F g 16) are lso u ed for l el m a urem nt n clo ed tanks Both tank c n necti n a e s ppl ed w th ga t pr ssu e sl ghtly h ghe th n the ma mum wh ch c n occ r n th t nk Th gas flow a l m t d by estri ti n or ne dl al nd a e oft me u ed by rot mete s Th ga flow n each lin mu t be larg e ough to p nt l quid from ntering the lead l nes and to e ure a c t d ngs It mu t be small en ugh t k ep th pres u drop between th ma ometer t p and the t nk at a minimum Th m nom t r n t ns (taps) a e lo ated s lo e to the t k nnecti n a pos ibl

Liq id als ar occas o ally used on lo ed t nk l qu d l l m asu ments Seal ch mbe m t be

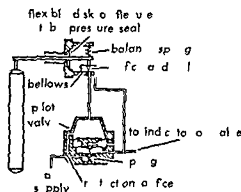


Fig 10 Force balance level unit (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

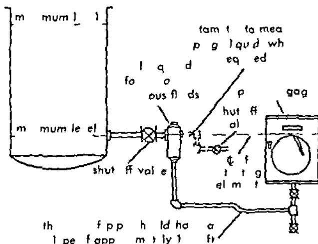


Fig 11 Pressure gage measuring tank level (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

Open tanks In open tanks the pressure measuring element is connected directly to the tank at or near its bottom (the reference or datum point) The pressure element may be located at any reasonable distance from the tank and at any desired distance below the reference point but the element responds to the additional head due to the liquid in the lead line Gas or vapor must be vented from the lead lines Pressure measuring elements when used in this way normally have suppressed ranges so that the zero reading occurs at the pressure corresponding to the bottom of the tank level With careful installation the pressure measuring element may be located above the reference point This installation requires a gas tight lead line venting only when the tank level is high and the maximum safe elevation of the pressure measuring element is the head corresponding to one half of atmospheric pressure less the vapor pressure of the liquid (Fig 11) Temperature changes on sloping lead lines cause density change and errors are introduced unless the pressure element has special compensation for this effect

To minimize lead line errors and venting trapped gas and gas purge systems have been developed These systems make it possible to locate the pressure measuring device at any reasonable distanc above the reference point The diaphragm box ma be installed directly in the tank or connected to i at the reference level A slack diaphragm separate the liquid from the trapped air or gas leading t the pressure gage The diaphragm has no prin constant hence the gas pressure equals that at th reference point and the remote gage indicates th head of the liquid with respect to the referenc point (Fig 12) The gas volume in the pressure measuring system is kept small to minimize th temperature effect and the compressibility effec with liquid level changes

On some installations a trapped gas system elimi nating the slack diaphragm can be used On the installations the gas must not be absorbed in th liquid and the liquid must not vaporize and con dense in the lead line to the pressure measurin device Provision is generally made for periodic ga checking and replacement In the gas purge system (Fig 13) a small quantity of gas is bled into th system continuously This gas is permitted to bub ble from the box or a tube with an opening at th reference level Purge rates of about 1 standard ft^3/hour are common Precautions are taken t avoid measurement of the pressure drop due t

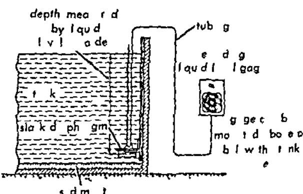


Fig 12 Trapped-gas level system using diaphragm box (Bristol Co)

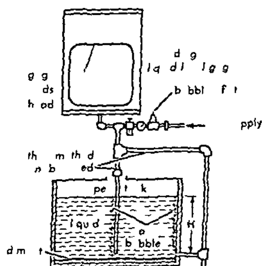
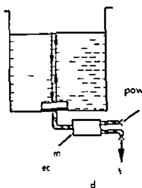


Fig 13 Gas purge level system (Bristol C)



ig 21 So l l g g (D M C d d P s Instrume t d C t I H db k M G w H II 957)

SOLIDS–LEVEL MEASUREMENT

S lids le l detect rs are u ed to locate the top of a pile of d ded l d in large ves els r pr ce s i g equipment The in truments are de ign d for the differe t l d handled and the in tall tion m t be car fully made to i ure pr per measure me t Be u e l ds fu nel c e and ary n a erage d ity w th the particl i e hape di tribut n m ture c ntent nd other fact s these dete t rs pr ide nly an appr ximat indicat on f the olume prese t or the top f tl e p le S l ds l el d tector are cla sified as o tinu o s or fixed p nt

Continuous detectors These pr ide co t nu ou mea rem nt of the l el o e the ange for which they were de gned Th o tput i a a alog repr entat n f the le l of the l d

The grid type eleme t (Fig 22) is ed n bed of finely d id d movi g particle and pro de cont nu s i d cati n of the lid urface The g d supp rted and weigh d by a n e t nal pn um t c sy tem the weight i crea ng as the mme on i c ea e Th s c tr cti m y be u ed i e l u der p e t

The γ ray mitter and det to di c s ed p e ly nd liq id l el mea rement is part cu la ly u eful n tl s rvice bec u e all the equip- m nt may be loc t d out de the es el

The beam cale and oth r weigh ng de ce are sed part cula ly on mall es ls a d pro es ing eq pm nt *S e* WEIGHT IEASUREMENT

Th capa t n e type le el dete to al o dis- cu ed und l quid le el m s em t is satis f tory for use on m ny finely di ded solids

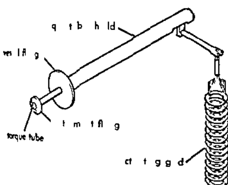
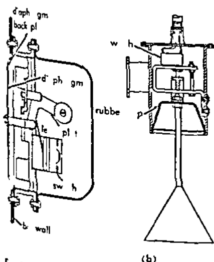


Fig 22. Grid-typ l m t (U O I C f C I lv)



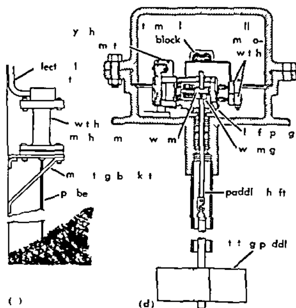


Fig 23. F ed-po t l ds-lev l d t ct ( ) D ivom-ope at d l l d t t (B n-D t C) & Pend nt one-type l l d t ct (S ph s-Ad m Mfg C) ( ) P obe-d fl ct typ l l d t t (G B L d m C) (d) R t t g p ddl wh l-typ l l d t t (F II C)

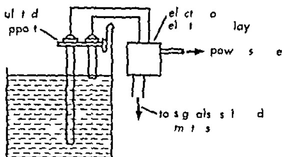


Fig 17 Conductivity probe type level system (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

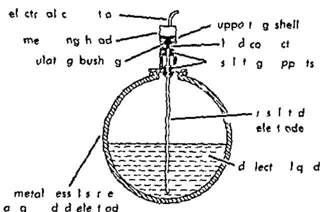


Fig 18 Capacitance probe type level system for dielectric liquid (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

installed at suitable locations and consideration must be given to the differential in the specific gravity between the sealing liquid and the liquid in the tank

Thermal elements may be used for level control when the temperatures of a liquid and of the vapor space above it differ appreciably Although standard thermal elements are used in some services a number of special designs offered for boiler service are particularly designed to handle the problem of boiler swell on increased steam demand The level devices in this group are not precision devices and are not used for measurement purposes

Electrode or probe systems These are used in various forms for level indication and control (Fig 17) The number of electrodes and their design depend upon the characteristics of the liquid and the application Fundamentally a circuit through a relay coil is closed (or opened) when the liquid contacts a probe Electronic circuits are used when the liquid resistance is high

Capacitance measuring devices If the liquid being measured is a dielectric insulated probes may be inserted into it and the capacitance of the assembly will vary with the immersion of the probes in the liquid (Fig 18) The dielectric constant of the liquid must be different from that of the vapor and errors will occur if either of these changes appreciably If the liquid is a conductor only one probe is necessary but it must be covered with an insulating coating (Fig 19) As the liquid rises on the probe the capacitance of the unit increases Although capacitance methods of measuring liqu[id level] have certain advantages (no moving parts corr[o]sion resistance) they have certain disadvantag[es] such as high cost susceptibility to dielectri[c] changes and susceptibility to electrical interf[er]ence Therefore this method of level measureme[nt] is limited to those applications which cannot [be] readily handled by other means

Nuclear level gages These are used for difficu[lt] applications Basically all of the units involve [a s]ource of gamma (γ) radiation and a detector [s]eparated by the vessel or a portion of the vessel [in] which a liquid level varies As the level rises th[e] detector receives less γ radiation and thus th[e] level is measured Numerous designs are availab[le] for special application needs one of which [is] illustrated (Fig 20)

Sonic level detector This is based on the tim[e] increment between the emission of a sound wa[ve] pulse and its reflection from liquid surface Th[e] sound wave pulse is generated electronically an[d] its time in transit is measured very accurately b[y] electronic means If the speed of sound in th[e] liquid or in the vapor is known accurately th[e] liquid level is known (Fig 21)

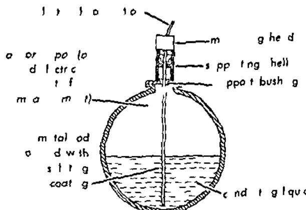


Fig 19 Capacitance probe type level system for conducting liquid (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)

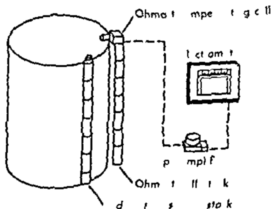


Fig 20 Gamma ray level gage (D M Considine ed Process Instruments and Controls Handbook McGraw Hill 1957)







A f fose l h P mel N t th p h ped p o t b h (F m H J F ll d O T pp eproduct e bod (b) C ust l h g w g po C ll g B t y d H ft 1954) rock (c) Usnea b bat frut l h g w g

bre masses of c lls and hyphae the pl t body as be f l (le fl ke) r sto e (ru tl ke) o fru cose (b ch n)

Reproduction R p d tio by f gmenta tion, eithe by the death of the old r p rts f the parent body o by pec l bod called o ed which are mall f gme ts f the th ll r ad ly h hed and d emi ated by a r cu ent In ad ditio b th egetat e m ans of rep d c ng the li hen s a t e h f the di idu l compo e t ma reprod e e th exually r sexu lly

Economic importance Th l h s a impo tant p ce soil b ld a fo d f r man d other anim l a o c f s h dy s l tm w bl a d cudbea f ia n and a t ure f ertain t l ls ed f th i etmati app l S ALGAE FUNGI [P V]

B g phy S e THALLOPHYTA

Licorice

A p od t obt ed f m the lic i pl nt *Glycyr rhiza glab* f the l gum family (Legum s e) It is a per l herb wh ch gr w both w ld and u cul tion i s uthern Europe a d in w tern A entral A a The r ts a d ed for eral m th and the p ck ged for hipment. Spa n leads in the p od ti n f c ltı ated l cor ce r ot Licori e is used in med c n t m sk objecti n ble a d as a la ati e as a fl i g m te l in the b ewing toba c nd ca dy i du t s and in th manuf ctu e of ho p li h S ROSALES S BA D FLA ORI G [P D S]

Lie detector

A useful appl cati n f the physiolog c l resp s of e ot on. The machi e is known as th p lygraph lie d ector and i w d ly u d i c ime d te ti n and in sec ty se s ti ea e s f empl yment The li d tect r pe ates the pri c pl r ass tion that lyi g n ol s n emot al re a on and that emoti n l re ct ns e char ct ized b phy l gi l change The phy l gical ch nges m red by l e d te t rs e changes in relat ve bl od pres ure hea t rate re pi ati n mo m nt and frequ ntly palmar sweati g o gal a c kin esp ns The ne essary apparatus is att ched to s pect who is then asked a ries f q e t ons t which he c n s mply nswer y or n Some f th q est ns ar n t l and serv to e tablish th ubject s characte sti re pon es to kn wn truthf l swer The significant qu tions o th wh ch pe tain t the rime a e phrased s th su pe t must either admit knowledge f th r m l e

Lying i b lie ed to i l e mot onal re p n beca e f the onfl ct between the trong cultu d c nd t ng fo tr thfulnes and th de re to cape dete ti n Pers ns lack ng on sc en mav till m ke an m tion l r sp n t lyi g if th y belie in the i fallib lity of the m hin

Ac rd g to r ew m de by D l W lfle in 1946 the c racy of the p lyg aph in pract 80% c rrect 3% wrong nd 17% not terp t able Th ac ur y depe ds t a gre t xtent on the skill f the ex mi er who must be tho oughl t ined and hould h ve e e al y ars f e pe ence

M st ourts do n t yet acc pt li detect re port a eviden lth gh onfe ions el cited by me f a l e det tor xaminat on may usually b epted [A F A]

B bliog aphy F E Inb u *Lie D tecti n d Crim nal I t r g t on* 2d ed 1948 *The Poly g aphic T uth T t A sympos um* T nessee Law Review 1 22 Febr ary 1953 D W lfle Sum mary f r port of ub omm ttee on m thod of l e detect n *Am J Psychol* 59 544 1946

Liesegang rings

Pe od p ecip tat n one bta d l y counte diffus on f solubl ub tances wh h f rm a slightly ol ble prec pit te I th se of ne d mensional d ff si th e zon s ar alled Li eg ng band Whe placing a drop of c ncentr ted s l er n t te s l ti n un n el s plate

Fixed point detectors These indicate when a specific level has been reached They are u ed mainly for actuating alarm signals By installing a number of these however at different points the combined respon e can be made to approach that of a continuous detector Four fixed point detectors are shown in Fig 23

Diaphragm operated level detectors are widely used for finely divided solids (such as wheat) in open vessels

The pendant cone and movable probe units used in large open vessels are actuated by the surface of the cone resulting from the piling of the material

The rotating paddlewheel level detector is driven continuously by a small motor until the paddle is stopped by the presence of solid material This device is widely used on finely divided solids in open ve sels [R E CL]

Bibliography D M Considine (ed) *Process Instruments and Controls Handbook* 1957

Lever

A pivoted rigid bar used to multiply force or mo tion sometimes called the lever and fulcrum (Fig 1) The lever uses one of the two condi tions for static equilibrium which is that th sum *mation of moments about any point equals zero* (The other condition is that the summation of forces acting in any direction through a point equals zero *See* INCLINED PLANE)

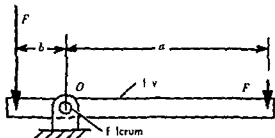


Fig 1 The lever p vots at the fulcrum

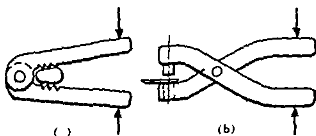


Fig 2 (a) Nutc acke (b) Paper Pu ch

If moments acting counterclockwise around the fulcrum of a lever are positive then for a friction le s lever

$$F_B b - F_A a = 0$$

thus

$$F_B = \frac{a}{b} F_A$$

If F_B is the output and F_A is the input the chanical advantage is

$$MA = \frac{F_B}{F_A} = \frac{a}{b}$$

Applications of the lever range from the im nutcracker and paper punch (Fig 2) to comp multiple lever systems found in scales and in t ing machines u ed in the study of properties of r terials *See* SIMPLE MACHINE [R M Pl

Libra

The Balance in astronomy is one of the 12 zodi con tellations Libra appears during the pring is the seventh sign of the Zodiac The con tellati consists of faint tars and is not conspi uous lies just west of the claws of Scorpiu The pr cipal stars outline a four sided figure re embling balance with beam and pans The balance mig have been held originally in the hand of Virgo zodiacal constellation nearby who was identifi with the Goddess of Justice Another possible re son for identifying the constellation with the b ance is that 2000 years ago the Sun was in Lib at the then autumnal equinox at which time da and nights are of equal length *See* CONSTELLATIO [C S Y

Lichens

A group of organisms having a dual nature th is algal and fungal components are combined in a plant that is distinct and consistently recogniz ble Over 15 000 species have been described B cause of the dual nature of lichen they do n readily assume a natural position in any plar classification They are widely distributed and o cur in a great variety of habitats Lichen may b found on bare rocks soil living tree trunk and dead wood of any kind They range from the arcti tundra where some species are found in such abun *dance as to provide pasturage for grazing animal* to the tropics where some of the bark lichens ar conspicuous Frequently they are to be found wher conditions are unfavorable for the growth of othe plants Most lichens are gray or grayi h green bu some are white orange yellow yellowish green brown or black In a few certain structural fea tures of the plant are brilliantly colored

Relationship The complete relationship which exists between an alga and a fungus as ociated in a lichen is not fully understood The relation hip has been cited as one of the best examples of sym biosis within the plant kingdom however some students of the group are not convinced that this is a reasonable explanation

In most lichens the algal component is a member of either the blue green algae (*see* CYANOPHYTA) or the green algae (*see* CHLOROPHYTA) The fungus component is usually a cup fungus (*see* ASCO MYCETES) or more rarely it is a club fungus (*see* BASIDIOMYCETES) The fungus usually forms a dense netw rk of interweaving hyphae enveloping the algal cells Depending on the configuration of





A foTose l h P m l N t th c p h p d po a t b ch (F m H J F ll r a d O T ppo prod ch bod (b) Cru t l h g w g p C ll g B t y d H lt 1954) rock (c) Usn b bat f h l h g w g

ee masses of c lls d hypha the pla t b dy a be f l ose (l af ke) cr t e (tl ke) or uticose (b an hin)

Reproduct on R p d t s by fragm ta on, the by th d th f the lde part of the arent bod o by p al b d c ll d o d hich a e sm ll f gments of th thall s ead ly ta hed a d d m ated by air c ents In ad ion to th g t t mean of r p od c ng th hen as a u t, h f the i d d l comp e t t rep odu e ith sex ally or e ally

Economic importance The l h n re imp ant p eer so l b ldes as f d f r m d d an al a e f h dyes l tm hil d c dbe a so of ta n d as o e f rt e ti l o l u d f th m t app l S ALGAE FUNGI [P A V]

B bl g phy S THALLOPHYTA

Licorice

A p od t bta ed f m the l c pl nt *Glycy rh a glab* of th legume fam ly (L gum o) It a p renn al he b wh ch gr w both w ld and n cult t n thern Eu op nd i we t rn nd centr l A The roots a e d ed for s al e h a d the p ckaged f r sh pment. Sp in leads in the p od tion of ult ated li ori e r ts Licorice is used in med cine t m k obje t on bl te and s a lax t e a fl ing mate l i th brewing t b c d a dy indu tri nd n th m uf t re f h e p l h *See* ROSALES SPICE AND FLAVORI G [P D S]

Lie detector

A w al pplicati of the phy logi l resp s of emotion. Th m ch ne i k own s the polygr ph lie d ect and is wid ly used i r me det ct n and in secur ty se ti e re s f employment

The li d tector ope te n the p i cipl assumpti n th t ly ng i ol es n mot on l e action and th t emot nal r a ti re ch ract ed b phy l gi l change Th phy ol g al al m red by l e d tect r a h ng relative blood p e e heart rate respiration mo ements and f eq e tly palmar sweating o gal kin re po The neces ary apparat is atta h d t a uspect wh i then asked erie f questions to wh h he can mply nswer y s or no Som f the q est s re ne tral and serve to e tablish the subject s ch racteristi respo s to k wn truthf l swers Th s gnific t que t or th which p t n to the r me are ph sed th suspect must e th admit k owledg f the crim r lie

Ly n belie ed to in l e a emotional re sp beca e of the flict b tween the strong ltured diti g for t thf l es and th de ire t e cape detect n Per ns lack g a n ce m y st ll m ke a em t n l re p nse t lying f they belie e the i f llibil ty of th m chi

Acc d g to a eview made by Dael Wolfl in 1946 th ccur cy of the polyg ph n pr ti e 80% o re t 3% wr g a d 17% not terp t able The a curacy d pend to a gr at e tent on the k ll of the exam ner who m t be tho ughly t i ed d sh uld h e sev al ye rs f e p ri nce

M t court do n t s yet acc pt l e dete t re port s e dence lthough conf ssio s el ted by me ns of a l e d t ctor exam ati n may usually be cepted [A F A]

B bliog phy F E Inb u *L e Det ct n a d Crim nal I terr g t o* 2d ed 1948 *The P ly g ph c T th Te t A sympos m* Tenn sse Law Review l 22 Feb uary 1953 D W lfle S m mary of r port f sub ommitte on method of l detect on *Am J P ych l* 59 544 1946

Liesegang rings

P iod prec p tat n z es bt ined by c nte diff i n f sol ble b ta ce whi h form a lightly l bl pr ipitat I the cas of n -d me o l d ffus n th e zo a e lled Lies ga g bands

Whe plac g drop of a once trated s l n tr t s l tio up a gl pl t co ered w th a

gelatin layer containing potassium dichromate R E Lie egang ob erved in 1896 that the resulting precipitation of silver chromate did not spread continuously or quasi continuously *but that indi vidual* precipitation zones eparated by zones free of precipitate evolved in the form of concentric circle Similar phenomena have been observed with many other reactions

Periodic precipitation is due to the interplay of diffusion and nucleation which requires a certain degree of supersaturation Assume that solute A diffuses from a fairly concentrated solution into a dilute solution of B The precipitate AB starts to evolve the initially high degree of super aturation drop and accordingly nucleation ceases Upon diffu ion of A into farther regions not yet depleted with respect to B a sufficient degree of supersatura tion is reached once more a econd precipitation zone evolves and o forth *See* PRECIPITATION (CHEMISTRY) [C W]

Bibliography E S Hedges *Liesegang Rings and Other Periodic Structures* 1932 K H Stern Liesegang phenomenon *Chem Revs* 57(1) 79–99 1954

Life origin of

The origin of life refers to the means by which living organisms arose on the earth which con *tained no life when it was formed While there is* little difficulty in telling whether a higher organism is alive there is no agreement a to what charac teristics would be required for the most primitive organisms in order to call them living The most outstanding characteristic of living organisms i their ability to reproduce Therefore the definition used here for a living organism will be an entity which is capable of making a reasonably accurate *reproduction of itself with the copy being able to* accomplish the same task Furthermore this organ *ism must be subject to a low rate of changes (mu* tations) that are tran mitted to its progeny

Spontaneous generation Until the nineteenth century it was almost universally held that life could arise spontaneously as well as by sexual or nonsexual reproduction The appearance of various insects and animals from decaying organic mate rials in the presence of warmth or sunlight was a common observation but this ob ervation was misinterpreted to mean that the inse ts and ani mals arose spontaneously

The Tuscan physician Francesco Redi performed the first effective experiments (1668) to disprove the hypothe is of spontaneous generation He showed that the development of maggots in meat did not o cur when the flask containing the meat was covered with muslin so that flie could not lay their eggs on the meat Lazzaro Spallanzani performed similar experiments (1765) showing that micro organi ms did not appear in various nutrient broths if the ve els were sealed and boiled Objections were rai ed that the heating had destroyed in the broth and air the vital force which was po tu lated as necessary for life to develop By readmit ting air it was possible to show that the brot could still support the growth of microorganism But Spallanzani could not demon trate that the a *in the sealed flask had not been altered and th* doctrine of spontaneous generati n per i te widely

The problem was finally solved by Louis Pasteu (1862) who used a flask with broth but in tead c sealing the flask drew out a long S haped tub with its end open to the air The air was fre *to pass in and out of the flask but the particle* of dust bacteria and molds in the air were caugh on the sides of the S shaped tube When the brot in the flask was boiled and allowed to cool no m croorganisms developed but when the S hape tube was broken off at the neck of th fla k mi croorganisms developed The e experiment wer extended by Pasteur and by J Tyndall to answe all objections that were raised and the doctrine o spontaneous generation was finally disproved

Origin of life theories Shortly before 1858 *Charles Darwin and A R Wallace had publi hed* simultaneously and independently the theory o evolution by natural selection This theory coulc account for the evolution from the simplest single celled organism to the most complex plants and animals including man Therefore the problem of the origin of life was no longer how each species *developed but only how the first living organism* arose To answer this question a number of pro posals have been advanced

It has been proposed that life was created by a supernatural event This has been a common be lief of many people based on a literal interpreta tion of the first chapter of Genesis which de cribes the creation of all living organisms by a d rect act of God This type of propo al is not con id *ered by most scientists since it is not subject to* scientific investigation

In 1903 S Arrhenius offered a second theory that life developed on the earth as a result of a pore or other stable f rm of life coming to the earth in a meteorite from outer space or by the pre ure of sunlight driving the spores to the earth One form of thi theory assumes that life had no origin but like matter has always existed The presence of long li ed radioactive elements shows that the ele ments were formed anywhere from 5 to 12 × 10 years ago If the elements have not alway exi ted it is difficult to understand how life could have al *ways existed Another form of this theory* assumes that life was formed on another planet and traveled to the earth This hypothe is does not answer the question of how life arose on the other planet In addition most scientists doubt *that any known* form of life could survive for very long in outer space and fall through the earth s atmosphere with out being destroyed Therefore while this theory has not been disproved it is held to be highly im probable

A third hypothesis held that the first living or ganism aro e from inorganic matter by a very im probable e ent This organism in order to grow in

m mo gan en iro m nt w ld h t synth ize ll f t ellul r c mp n t f m carb n dioxide t and the in g ni tr nt P e e t knowl edge f b och mi try h s th t even th mple t b en re e t mely c mpl x and th t the p ba b ity of th po ta e g ne t n f a cell f m rgan c mpound i a gle e t is mu h too small to h e curred in th ppro imately fi bil lion y ars e th arth fo matio

A r pl bl p p l th t l f ar se sp n t eo l in the oce n f the primiti e e rth which co t med l g q t t s of o g m pounds mil t th whi h in l r ganism Th the ry a utlined m nly by A I Op n (1938) d form th b s of mo t f th pres t id s o the igin of l f Opa n g d that f large m ts f o g nic c mpo nd were in the ocea f the p imit earth these rg c m pounds ld r t t form t uct re f gr ater a d gr te c mpl xity til t t e wo ld form h h ld be called l ving In th w d the synth f the first l g o gan sm w ld i ma y nb l gical tep nd n e f these e ould be h hly imp bable

Oparin also p p d th t ga mp und might ha been f rm d the p m ti e th f there red ing atm phe f m th e am a t d hyd oge i te d f th p nt during tmo ph f b n d d t ge gen and w te H C U y (1952) pla d the forming tm ph theory fi m f dat n b th ing th t meth n mmo a, a d w te e the tabl f rms f l n t og a d yg n f t e es of hyd g n p e t Co m c d t th d fr m wh h th e rth i b l e d t h been f rmed ntain a great e e f hyd g n T pl net J p t S t and U a k w to have atm ph of m th e d mm n a O d ring d t h devel p d Me ry Ve nus th Earth d Ma s d t the p f hy

d n f ll w d by th pr du tion of oxyg n by the ph t h m l pl tt g of wat r There has not l n uffi ent t me f th hyd n to ha e e p d f m J p te Satu U Nept n and Pl t w g to th lowe temp t d h her g t ti nal tt t n

Origin of organic compounds M y tt mpt l a b n m d t ynth e rg i mp d u d r x d g d t n u g ca b n d de and water with va f n gy h s ultra iolet li ht ele tri di h rg d h h n e gy adiation All of th e expe m t f led t g e org nic compo nd e cept i e t m ly sm ll y eld

S pp t f the ideas of Opa i and U y me from xpe m t by S L Miller (1953) H showed that m t re f meth ne ammo ia w te d hydr ge wh n bjected to an electr d h g g e significant y ld f mple ami acids hyd y ds aliphatic a d ea nd p s bly s g Ult v let l ght gi es m l e lt

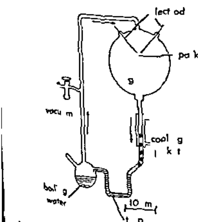
O th b f the e e p m t t s thought th t a io g mp unds (u h ami o a id hyd y ac d l ph t ac ds a d ug s) w e pre t n the ce f th p mit th It t ll ec sary t h w me ha m f tl e f mat o f p lypept des p n d py m di (th b e wh h u n l ds) n leo t des and p lynu leot d o r f pho ph te b nd e e gy (n de e t pl phat) yn thes f p lypept d w th talyt ti ty (zym) a d the de l pm t of p ly le t d p ble f lf d pl t n

Nature of first organisms In p t l o n m th d pl t p ceed by d pl ti th g f ll w d by s th f m e zym d th ell n t t d d o f th c ll i to two f gm t The g wh h l c t d n the h m m a mp ed f p ly leo tid all d de xyr b nucl d S CHRO O SO E GENE NUCLEIC ACID

S n th e tal h t r t f l g ga m i th ability t d pl ate t h s b r p o- p d th i th fi st l g o g m w e mply tr p f deoxy bon le a d (o p h p t p f b nucl c d) wh h t geth w th th n v nzym s uld d pl t Th g n m would be m l t u pt th t t w ld h th e es ry nzymes f r it ep od cti n

Th v s t f e l t p f n le d r d d by t f p t Th u s p bl f d pl ti n b t ly w th n ther l ll whe th r m k s u f the ll zymes d m tab l m S n e th u *an e-* p d e t elf b t ly w th n l in ll th r i d bl d p t t wh th a u h uld b lled l g t In a y c m y l g t *bel* e that th s w t th fi t typ of l g g n m b t th t t gr s n f m m d ed type f g m *S e* VI us

It h b p p d by A I Op in that th fi t g m w c rv te p t l n tead of



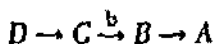
Apparatus used f p od ct f m id by e disch g Wat b l d m ll fl k ing th gase l g fl k wh p k l t d products of th disch rg d d p th gh tube, nd ac l t m ll fl k

strips of polynucleotides A coacervate is a type of colloid which forms two phases one of the solution and one of the coacervate instead of a uniform dis persion as with most colloids It is assumed that there would be some coacervate particles which could absorb proteins and other substances from the environment grow in size and then split into two or more fragments which would repeat this process In time the duplication would become more accurate and the genetic apparatus of nu cleic acids would then develop *See* COACERVATION

These ideas about the nature of the first organ isms are based on the assumption that the first forms of life were similar to present organisms in their basic chemical composition All present or ganisms contain proteins nucleic acids carbohy drates and lipids While the assumption may be in orrect it is the best working hypothesis until it can be shown to be inadequate Other possibilities for the development of the first organisms can be enumerated but so little is known of the composi tion of the primitive oceans that such speculation is not profitable

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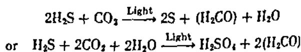
where a b and c are the enzymes and A B and C are compounds which the organism cannot synthe size If the necessary compound A becomes ex hausted from the environment then the organism must synthesize A in order to survive But it is ex tremely unlikely that there would be three simul taneous mutations to give the enzymes a b and c However a single mutation to give enzyme a would not be unlikely If compounds D C and B were in the environment when A was exhausted the organ ism with enzyme a could survive while the others would die out Similarly when compound B was ex hausted enzyme b would arise by a single [illegible] tion and organisms without this enzyme woul[d die] out By continuing this process the various ste[ps of] a biosynthetic process could be developed th[e last] enzyme in the sequence being developed first [and] the first enzyme last

Energy and biosynthetic processes It is n[eces]sary for all living organisms to have a sour[ce of] energy to drive the biochemical reactions that [syn]thesize the various structures of the orga[nism] The quantity that measures the available en[ergy] for a chemical reaction at constant tempera[ture] and pre sure is termed the free energy (*see* [FREE] ENERGY) Animals obtain their free energy [from] *the oxidation of organic compounds by molec[ular]* oxygen Plants and other photosynthetic organ[isms] obtain their free energy from the energy of li[ght] There are also many microorganisms that ob[tain] their free energy from fermentation reactions [For] example the lactic acid bacteria obtain their [free] energy from the reaction



$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Lactic acid}}{2CH_3CH(OH)COOH}$$

Yeasts also ferment glucose but they prod[uce] ethyl alcohol and CO_2 instead of lactic acid [And] there are bacteria which carry out many ot[her] types of fermentation reactions It is likely that [or]ganisms obtained their free energy from ferme[nta]tion reactions until the supply of fermentable c[om]pound was exhausted At that point the devel[op]*ment of photosynthetic organisms which* obt[ain] their free energy from light would become nec[es]sary The porphyrin substance chlorophyll seems [to] be necessary for all types of photosynthesis a[nd] would have had to be present in the environment [or] its biosynthesis developed in some way The fi[rst] type of photosynthesis was probably similar to th[at] of the sulfur bacteria and blue green algae whi[ch] carry out the reactions



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where (H CO) means carbon on the oxidation le[vel] of formaldehyde (carbohydrate) It is much ea[sier] to split H_2S than to plit H_2O and o it wou[ld] seem likely that organi ms would develop phot[o]synthesis with sulfur first When the H S and [...] were exhau ted it would become nece ary [to] split water and evolve O the hydrogen being u[sed] for the reduction of CO *See* CHLOROPHYLL PHO[TOSYNTHESIS]

When the methane and ammonia of the primiti[ve] atmo phere had been converted to carbon di xid[e] and nitrogen by photochemical decompo ition [in] the upper atmosphere water would be decomp[os]ed to oxygen and hydrogen The hydrogen w uld e[s]cape leaving the oxygen in the atmo phere an[d] thereby resulting in xidizing conditions on th[e] earth It is likely however that mo t of the oxyge[n] in the atmosphere was produced by the phot [os]yn

thesis of plants rather than by the photochemical splitting of water

Multicellular organisms The evolution of multicellular organisms probably occurred after the development of photosynthesis The evolution of primitive multicellular organisms to more complex types and the development of sexual reproduction can be understood on the basis of the theory of evolution. S EVOLUTION ORGANIC [S L M]

Bibliography E. S B rghoorn Origin of life *Geol. Soc Am M m* 67 2 75–86 1957 J D Bernal, *The Phys cal Basis of L fe* 1951 S L. Miller A producti of am a d under p s le primitive earth conditions *Science* 117 528–29 1953 S L. Miller Product on of ome organ c compou ds d possible p m t e e rth cond tions, *J Am Chem S* 77 2351–2361 1955 S L. Miller a d H C. Urey O g nic compound forma tion on th p imiti earth *Sc e c* 130 245–251 1 9 A I Oparin *The O g of L fe* 2d ed 1953 G. Wald, The ori in of l fe *Sci Am rican 191(2)* 45–53, 1954 Sympo um Modern idea sp taneous ge er tion, *A n N Y Acad Sci* 69(art. 2 25 376 1957

Ligament

A strong fl xible c n ctiv tissue band usually found bet een tw bo y p om ences Most liga ments are composed f de e fib o *o necti e t s*-sue formed by par llel bundles f collage fibe s They ha e a hi ing l ery appeara ce and are pliabl but o el sti This typ also m y f m part f a joint c p l o a art lar s rface un der synovi l memb e uch a ociat d t n dons S Bo E (BIOPHYSICS) CONNECTIVE TISSUE.

Another k d of l g m nt i omp sed e th partly r alm st nt r ly of yellow elasti t ue which is ext n ble The large l gam ntum nuchae at the ba k of th neck a d th ligaments between vertebrae are of this typ a d permit the b ding of neck nd trunk [E C ST]

Light

The term light, a c mmonly u ed refers to the kind f rad t electromagnet c ne gy that s-ated ith vi on. In a b o d en e light in c d the ent e ange of r d at o known the electrom gneti pectrum Th b a ch of ence dealing with l ght, t o igi nd p pagat it effects, and the phe me a a s iated with t called pt cs Spe t scopy the bra ch f with t pert t the prod t on nd in tig tra f pect

A acceptabl theory f the n tu e f l ght mu t ra f om beerv t r ga d ng ts beh or ... th a b ef a unt f the p i ip l f ts ... a abo t ble l ght i cl d g th r l t on ... light t the lectr magn t c pe tr m a ... a d th n de tribe the app r t dual ... f light. The m d *r of th* t le d s- ... rou e per m tal a d th o et cal n ... n pert n nt t th tudy f th p bl m

PRINCIPAL FACTS REGARDING LIGHT

Finite velocity The fact that light travels at a finite peed or el c ty is well established both theo etic lly and e perimentally This speed is so high howe er a d the experime tal complexities of me suring it a e so great that th s is not a phen men n the a e age man c n check fo him elf The fi st succe ful measu eme t of the speed of l ght was mad 1676 by the Danish astronomer Ol R eme a d n e that t me nume ous in crea ngly precise xperim nts ha e been con ducted leadi g to th c rently accepted value of 299 792 8 km/sec n ac um I ound numbers the speed of light in vacu m r ai may be aid to be 186 000 miles/ ec or 300 000 km/ ec

Diffraction and reflection On of the mo t ea ly b erved facts about light ts tendency t tra l t aight l es Caref l b erv tion hows howe er th t a l ght ray spread l ghtly whe pass g the edge f n bstacle This phen me n called diffract n The reflection of l ght s al o well kn wn The earth mo well as all other satell tes and pl ets in the solar y tem are ble nly by reflected l ght they ar t self lum us l ke th s Reflecti n f l ght from sm th opt al surfaces occ rs o that the angle f reflect n equals th angle of inc d e fact th t i most eadily ob erved with a pla m rror Wh n light re fl cted irregularly d diff sely the phenom n n is t rm d catter g The scatte g f light by ga pa ticles the atmosphere c u es the blue lor of th ky Whe h ge in f q ency (or w e *length) of the light* o s dur g c tte ing the scatt g is referr d to as the R m n effect

Refraction The typ f be d g of l ght ray call d ef acti caused by the fact th t light t a els at differe t pe d in d ff ent med — fast r fo exampl n air than in either gl s wate Refract on occur when l ght passes f om one med m into an the in whi h it mo at a differ t peed F miliar ex mple incl de the cha g n direct n of light ays n goi g th ough a pr m and th bent appe ran e of stick par tially mmersed n water

Interference and polarization In the phe me non call d interf nce rays f l ght em gi g from tw parall l lits c mb e on a s een to prod alternat g light and dark ba ds This *eff* t n be bt ned q ite ily n the labor tory d i bs rved i the c l r prod ced by a th film of o l n the fa of pool of water Pol rizat on of l ght s ually how w th P l oid d k S ch d k e qu te transp ent i d d ally Whe tw of them pla ed t gether how the d gree of t spa e cy f the omb ti n de p nd p n the l ti te t t n of the *d ks It* an b ed f m eady t a m ion of l ght to alm st tot l opa ty mply by tati g n d k with pect t the th

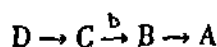
Chemical effects Whe l ght ab bed by rta bsta s h mic l ch ges t k pl e Th f t f rms th ba f r th e c of photo-

strips of polynucleotides A coacervate is a type of colloid which forms two phases one of the solution and one of the coacervate instead of a uniform dis persion as with most colloids It is as umed that there would be some coacervate particles which could absorb proteins and other substances from the environment grow in size and then split into two or more fragments which would repeat this process In time the duplication would become more accurate and the genetic apparatus of nu cleic acids would then develop *See* COACERVATION

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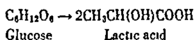
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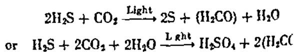
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terferenc d ffraction polarization

rect ea pr pag ion re act reflect

wave theory of lig — vygen A. resne lord ayle)

geometrical optics — (Desca es f rma

black bod rad ion

vantum theory of radiation — (M. Planc)

electromagnetic theory — (J. C. Maxwell ertz)

po no re of mo d scre ect ch rges pectra

quantum mechanics — (Bohr A. Sommerf ld)

hotoe ectric ect

photon theory — (A. E)

interactions between electromagnet fie and moving electron, positron ... magnet moment electron, fine structure of hydrogen atom (Lamb)

pectra Compton effect lectro ac

wave mechanics — (d oq W se be E Schrod nger)

uc ea ons m so ementary pa les ec om etic fie d

ectrodynamics of mo g bod ea h or er velocity of

specia theory of relativity — (A.)

quantum electrodynamics — (A. M. Dirac W senberg ou W ssk pf wo Bethe llars Schwinger ayn)

vantum field theory — (A. M. rac, W se berg W W op Bethe lo Sc ng)

relati istic quantum theory — (M rac)

he nd nergy con rad on nd energy gravita ion nd propa ation

general theory f relativity — (A.)

unified fie theory — A. n. W

heory of li ht

Fig 1 Devel pm ts th th ry f l ght (G W St k)

fand t l m la ty b d mon trat d n ... l exp m nts The w e p t of th ... pect um of l ct mag et d t ... con n t gly h wn by th m l r ty of d f ... p t e pr d ced o ph tog phi pl t ... ed t somed ta b hi d d ff a t g t g ... d t n f d ffe t f q nc h a ... f l ght ... m reo ery m lar t t te ... f lectr n ally prod ced m c w d ... es

P l rizat n dem tr te the tr e h ... f l ght w ve F rth r of f th ele tro- ... ha t f l gl t f d n the p ... d ng tra sp nt body th t ... ed l y be m f l polar ed l ght ... property f t t g th pl n f p l r zat ... t m wh n th l ody pla ed a m g et ... See FARADAY EFF CT

The f t th t th loc ty f l ght h d bee ... ted f m lect d m g t c p m te

(pe m tt ty d p rmeab l ty) was at the o t f Maxwell s clu n 1865 th t l ght clud he t nd th r rad at n f a v a d t b n e the fo m f w p p g ted c ding t lect magn t law Fi lly the b erv ti n that le tr ns and t o g e t diff t on patte n q t mil to tho p du ed by ... ibl l ght h m d t n s ry to sc ibe the wa e ha a ter to part cle See ELECTRON DIFFRACTION NEUTRON DIF R CTION

Velocity d t m tion The fi te el ity of t a m f s g l by mean f l ct ma et c wa a f ct well t bl hed f ll w e- l ngths f ad t n a r t f terre trial nd t om al p r ment A tro m l bserva t f o-c lled l p ing b ies l th al and pect o p t k t nd c te that the eloc ty f l ght d ted by c d es n t d p nd n th loc ty f the e S B NARY STAR

M a em t f c f ll ba all t tw g o p (1) g p lo ty r gnal v l t d term na

chemistry Rapid progress has been made toward an understanding of photosynthesis the proce s by which plants produce relatively complex substances *such as sugars in the presence of sunlight* This is but one example of the all important response of plant and animal life to light

Electromagnetic spectrum The electromagnetic spectrum is a broad band of radiant energy which extends over a range of wavelengths running from trillionths of inches to hundreds of miles wave lengths of visible light *are measured in hundreds of* thousandths of an inch Arranged in order of in creasing wavelength the radiation comprising the electromagnetic spectrum is termed gamma rays x rays ultraviolet rays visible light infrared waves microwaves radio and TV waves and very long electromagnetic waves Detailed de criptions of these radiations are given separately *see* ELECTROMAGNETIC RADIATION and the articles listed therein *See also* ABSORPTION (ELECTROMAGNETIC RADIATION) DIFFRACTION INTERFERENCE OF WAVES OPTICS PHOTOCHEMISTRY PHOTOSYNTHESIS POLARIZED LIGHT RAMAN EFFECT REFLECTION (ELECTROMAGNETIC RADIATION) REFRACTION OF WAVES SCATTERING (ELECTROMAGNETIC RADIATION) SPECTROSCOPY

NATURE OF LIGHT

Early in the eighteenth century light was generally believed to consist of tiny particles Of the phenomena mentioned in the preceding section reflection refraction and the sharp shadows caused by the straight path of light were well known and the characteri tic of finite velocity was suspected All of these phenomena except refraction clearly could be expected of streams of particles and Sir Isaac Newton showed that refraction would occur if the velocity of light increa ed with the density of the medium through which it tra eled

This theory of the nature of light seemed to be completely upset however in the first half of the nineteenth century During that time Thomas Young studied the phenomena of interference and could see no way to account for them unless light were a wave motion Diffraction and polarization had al o been in estigated by that time Both were *easily understandable on the basis of a wave theory* of light and diffraction eliminated the harp hadow argument for particles Reflection and finite velocity were con istent with either picture The final blow to the particle theory eemed to have been struck in 1849 when the speed of light was measured in different media and found to ary in just the oppo ite manner to that a sumed by Newton Therefore in 1850 it eemed finally to be ttled that light consi ted of waves

Even then howe er there was the problem of the *medium in* which light waves tra eled All other kind of waves required a physical med um but light tra eled through a vacuum—fa ter in fact than through air or water The term ether wa pro po ed by Jame Clerk *Maxwell and his contempo raries* a a name for the unknown medium but this scarcely olved the problem becau e no ether ever actually found (*see* ETHER HYPOTHESIS) near the beginning of the twentieth century certain work on the emi ion and ab orpti energy that eemed to be under tandable o one assumed light to have a particle or corpu nature The external photoelectric effect th the emi ion of electrons from the surfaces of when light is incident on the surface wa c these At that time then cience found it elf *uncomfortable position* of knowing a con ide number of experimental facts about light of some were understandable regardle s of wh light consisted of waves or particle other peared to make sense only if light were wav and still others seemed to require it to have a ticle nature

THEORY OF LIGHT

The study of light deals with ome of the fundamental propertie of the physical world is intimately linked with the study of the prop of submicroscopic particles on the one hand with the properties of the entire univer e o other The creation of electromagnetic radi from matter and the creation of matter from r tion both of which have been achie ed prov fascinating insight into the unity of phy ic same is true of the *deflection of light beam* trong gravitational fields uch as the bendir starlight pa sing near the sun

A classification of phenomena in olving according to their theoretical interpretation ides the clearest insight into the nature of l When a detailed accounting of experimental i *required* two groups of theorie appear wl in the majority of ca es account eparately fo wave and the corpu cular character of light quantum theories seem to ol iate que tions cerning this *dual* character of light and make classical wave theory and the imple c rpu c theory appear as two ery u eful limiting theo It happens that the wave the ries of light can with a considerable part of the pl en mena vol ing electromagnetic radiation Ce met optics based on the wave theory of l ght can *many of the more comm n pr l lems of the prop* tion of light such a refraction pro ided that limitations of the underlying theory are not di garded *See* OPTICS GEOMETRICAL

Phenomena in olving light may be cla ed three groups electromagnetic wave phen m corpu cular or quantum phenomena and relati tic effects The relati istic effect appear fluence similarly the ob ervation f both corpu lar and wa e phen mena The maj r de el pme in the theory of light lo ely parallel the ri e modern phy ics The e development are cha in Fig 1 and are di u ed in the remai der this article

Wave character of light Interfere e and *fracti n me ti ned* earlier are tl mo t striki manife tations of the wa e character of light Th

terference
d ffraction
polarization

rect near
ropag on
re rac
re ection

wave theory ght
C uygens A resne
Lord Royle]

geometrical optics
(De rte rm)

b ac bod od on

vantum theory of radiation
(M. Planck)

electromagnetic theory
(J Maxwe Hertz)

particle na re ma er
scr ectric ch rg
spectra

quantum mechanics
(Bo A. Somme ld)

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photon theory
( )

spectra Com ton ect
lectro d raction

wave mecha ics
(de Brog W se berg
Sc röd)

uc ea forces m son
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lectromagnetic
fi

ect od cs mo
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special theory of relativity
(A. te)

quantum electrodynamics
M. Dirac, W senberg
S. W isskopf
owe, H. Bethe V llars,
Schwinger Feynma)

vantum field theory
A. M. rac W senberg
W W sskop
Bethe V lars
Sc ng m]

rela ivistic quantum theory
(P M. rac)

ert nd rgy co en
f rg
ravita ion nd propag ion

general theory of relativity
(A.)

unified field theory
A. ns W yl za

theory of lig

Fig 1 Develop ts th th ry f l ght (G W St k)

ha ent l m l ty b d mo t ted ı a
number of pe m ts The wa e pe t f the
entire pertrum f lect m gn tic r d at o is
ı to gly h w by th s m l r tv f d f
tary p ctures prod ced n a phot gr ph pl t
pl ed t m d ta e b hind a d ff t o g at g
h radiat f d ff t f eq en e s ch s
m d bl li ht The t fe ce ph m
of l ght m ow very s m l r t ı t
before f elect n lly p od ed m w e d
n es

Polarizat n d m tr tes the tr e h r
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chemistry Rapid progress has been made toward an understanding of photosynthesi the process by which plant produce relatively complex substances such as sugars in the presence of sunlight This is but one example of the all important response of plant and animal life to light

Electromagnetic spectrum The electromagnetic spectrum is a broad band of radiant energy which extends over a range of wavel ngths running from trillionths of inches to hundreds of miles wa e lengths of visible light are measured in hundreds of thou andths of an inch Arranged in order of in creasing wavelength the radiation comprising the *electromagnetic spectrum is termed* gamma rays x rays ultraviolet rays visible light infrared waves microwaves radio and TV waves and very long el ctromagnetic waves Detailed descriptions of these radiations are given separately *see* ELEC TROMAGNETIC RADIATION and the articles listed therein *See also* ABSORPTION (ELECTROMAGNETIC RADIATION) DIFFRACTION INTERFERENCE OF WAVES OPTICS PHOTOCHEMISTRY PHOTOSYNTHE SIS POLARIZED LIGHT RAMAN EFFECT REFLEC TION (ELECTROMAGNETIC RADIATION) REFRACTION OF WAVES *SCATTERING (ELECTROMAGNETIC RADIA TION)* SPECTROSCOPY

NATURE OF LIGHT

Early in the eighteenth century light was gen erally believed to con ist of tiny particles Of the phenomena mentioned in the preceding ection re flection refraction and the harp shadows caused by the straight path of light were well known and the characteristic of finite velocity was suspected All of th se phenomena except refraction clearly could be expected of streams of particle and Sir Isaac Newton showed *that refraction would occur* if the velocity of light increa ed with the density of the medium through which it traveled

This theory of the nature of light seemed to be completely up et however in the first half of the *nineteenth century During* that time Thomas Young studied the phenomena of interference and could see no wa to a count for them unless light were a wa e motion Diffraction and polarization had al o been inve tigated by that time Both were ea ily understandable on th basis of a wave theory of light and diffraction *eliminated the* harp hadow" argument for particles Reflection and finite velocity were consi tent with either picture *The fina*l blow to the particle theory eemed to have been struck in 1849 when the speed of light was measured in different media and found to vary in just the opposite manner to that as umed by *Newton Therefore* in 1850 it eemed finally to b ettled that light consi ted of waves

Even then *however there was the problem* of the medium in which light wave traveled All other *kinds of* waves required a physical medium but light traveled through a vacuum—fa ter in fact than through air or water The term ether was pro po ed by Jame Clerk Maxwell and hi contempo raries as a *name for* the unknown medium but thi scarcely solved the problem becau e no ether w ever actually found (*see* ETHER HYPOTHESI) Th near the beginning of the twentieth century ca certain work on the emi ion and ab orption energy that eemed to be understandable only one assumed light to have a particle or corpu cu nature The external photoele tric effect that the emission of electrons from the urfaces of ol when light is incident on the surface was one these At that time then cience found it elf in t uncomfortable po ition of knowing a con iderabl number of experimental facts about light of whi some were understandable regardles of wheth light consisted of waves or particles other a peared to make sen e only if light were wavelik and still others seemed to require it to have a pa ticle nature

THEORY OF LIGHT

The study of light deals with ome of the mo fundamental properties of the phy ical world an is intimately linked with the tudy f the properti of submicro copic particles on the one hand an with the properties of the entire univer e on th *other The creation of electromagnetic radiatio* from matter and the creation of matter from radi tion both of which have been achieved provide fascinating insight into the unity of phy ics Th same is true of the deflection of light beams l strong gravitational field such a the bending o starlight pas ing near the sun

A classification of phenomena involving ligh according to their theoretical interpretation pro vides the cleare t in ight into the nature of ligh When a detailed accounting of experimental fact is required two groups of theories appear which *in the majority of cases acc unt eparately for th* wave and the corpuscular character of light Th quantum theories seem to obviate que ti ns con cerning this dual character of light and make th classical wave theory and the imple corpu cular *theory appear a two very u eful limiting theorie* It happen that the wave theories of light can ope with a considerable part of the phenomena in olving electromagnetic radiation Geometrical optic based on the wave the ry of light can olve many of the more comm n pr blem of the propaga tion of light su h as *refracti n pr vided that the* limitations of the underlying theory are not di re garded *See* OPTICS GEOMETRICAL

Phenomena involving light may be cla ed into three group electromagneti wave phenomena corpuscular or quantum ph en mena and relativi ti effe ts The relati i ti ffects *appear to in* fluence similarly the ob ervation of both corpu cu lar and wa e phen mena *The major dev l pments* in the theory of *light clo ely p rallel the ri e* of modern phy ic Th e devel pment *are charted* in Fig 1 and are d cu ed in the *remainder f* this arti le

Wave character of light Interferen e and dif fraction mentioned earlier are the mo t triking manifestati ns of the wave charact r of l ght Their

n also be hown that the p th betwe n any points in thi sy tem is that which mi mize ime f r the light to tra l betwe n the points mat s principle) Th s p th would not be a ght line unless ι = 90 or ι = ι

ell's l w states th t n sin = n sin where called th nd x f ef ct on of the med um llo s that the r fract e ndex of a medium ι

r' becau e the r fractive index of a vacu m er c has the al l

spe sion The d per on dι/dλ of a medium e d be obtained fr m measureme ts f the r e index f d ff ent wa elength of l g t : eight of exper m nt l e id nce ba ed on as- nom al ob erv tio s is ag i t a di pe o in a Observat o of th l ght re ch ng the earth n the eclip ing b nary star Al ol 120 l ght years a t (1 l ght y a ~ 6 × 10 miles is the dis te tr d in acuum by a b am of l ht i ear) ho th t th l ght f all lo s s re- sed multaneou ly The ecl psi g occurs every h urs and 49 min Wer the e a diff e c of ve ry f t d light a d for blue light in i te tel ace as gr at a n part in 10 th s ta ould sh a m a ur ble time d ff en in the o rren of the eclips s i the e two of rs

Corpuscular nature of light In t i te a tion th matt r light ex hange nergy nly in di t am ints c lled qu ta This fact is difficult reco ile with the id a th t l ght e gy r e d o t in a w e but easily sual ed i m f rpu le r photon of light

B k b dy (h at) d ation Th r d at on fr m m t lly p rfe t heat d ator alled bla k des in l es th e chang f ne gy between t n a d m tte in a encl ed ca ity The b- ned frequ n y di tribu i n l the ad t on emitt d by the en l u e at a given t mp ratu e of the y n be orre tly described by theory only if e a umes th t light of freque y i absorbed i nt gral mult pl of a quant m of n rgy equal where h i fu damental phy cal o stant lled Pl nck co ta t Thi sta tl g d p rture m cla l phy ics w s made by M x Pla k at the t e t eth c nt ry

Ph t l tric ff ct When a mono h m ti m f e ct om gn tic rad at n llum n tes th e of a sol d (o l mmo ly a l qu d) rons a e eject d f om th rf c i th phe enon k own as ph t em i n o the ext rnal b oelect ic ffect The ki etic en g f the ns an be m a red el t i ally by m n f a collect r wh h neg t l h rged w th r ct to the em tt g s rf It is f und that th n f thes photoele trons a they d mmed te nd ndepe d t of the ten f th l ght beam even t ry l w l ght n ties. Th f ct ex ludes th p ib l ty f ac n l t n f en rgy f m the l ght b m unt l a t rrespond g t the k net e rgy f th ed lect n h s been re hed The n mbe f t n p rt al t the i t n t f th in ed be m Th loc t es f th elect n eje ted by light at arying frequenc s gree with the equa tion

$$\frac{1}{2}mv^2_{max} = h(\nu - \nu_0)$$

where m is the mas of the electron v_m the maxi mum ob erved el city the f equency of the il luminat ng light be m nd ν_0 a thr shold f quency charact i t c of th em tting ol d

In 1905 Albert Ein tei showed th t the photo-electric eff ct uld be a counted for by a uming that if the inc dent l ht is compo ed f photons of en rgy h p rt of thi energy h is u ed to ov re me the f ce b nd n$_e$ the elect on to the urfa e The e t of th energy appears as kinet ene gy of the jected electron

Compton effect Th e catter ng f r ys of fre-quency by the lighte elements au ed by the c ll i n f x ay photo s with ele tro Un d r ch i um tan e b th a atter d x ray pho-t n nd a scatte ed el ctr n are ob erved a d the tte ed x ay ha a lo er frequency than the m pi g x ray The k etic n rgy of the imping ng x r y the cattered r y and the att red el ctr n a w ll a th ir relat e d e tion a e in agreement w th alculati n in ol i th on s rvat o of e ergy nd moment m S COMPTON EFFECT HEAT RADIATION PHOTOELECTRICITY PHOTON

Quantum theories Th need fo reconcil ng M xwell th y f the el ct omagn ti fi ld whi h de c be the ele tr magnet c wa e hara te of l ght with the part cl n t r of ph t ns whi h d monstrates th equally imp rtant co pus ular h racte of li ht h ulted the formu lation of everal th ies wh h g a l ng way to-wa d g ng a at fact ry un fied tre tme t of th wa e and the co pu i la pi ture The e theorie n rp r te e ha d the theory of q antum el ct dyn m c fir t t f rth n rti l s by P A M Dirac P Jo d W Heisenberg d W Pauli d on the the the earl er quantum me han s f L d Br gl Hei enberg and E S hr d g r Unr s l ed theor t c l d fficult es pe si t howe er n the higher than fi st appro i mati s f the t cti n b tween l ght nd ele mentary part le Th n orpor t on f a the ry of th nu leus nto a the ry of light s bound to call f r dd t n l fo mulat on

Di c s synthe f the wa e and o p cula theori s f l ght s ba ed n rewr ting Maxwell s equ t ns n Haml t i n f rm re embling the H m lt n an qu t ons of las l m ch s U ng th me formal m l ed in the t nsf m t of cl c l to wa e me ha l equati n by th t od t on f the q antum f a t n h D c bta ed n w eq t n f the l tromag t fi ld Th luti f thi equat n r qui quant d w o r po d ng to ph t n Th p p tion f th e l t n rep nts th lect magn t field Th qua t z d wa s re ub-je t t H senb rg n t nty p in pl The q nt ed de cript n of d ti n c n t be t k n l t r lly t rm f e th r ph tons or w es but

tions using the relation c = distance/time and (2) phase velocity or wave velocity determinations using c = frequency/wavelength

The group velocity is the average time for a light signal that is a modulated electromagnetic wave train to traverse a given distance (*see* GROUP VELOCITY) Romer's original determination of the velocity of light was based on careful observations of the time of eclipse of the moons of Jupiter from various points in the earth's orbit Subsequent terrestrial determinations making use of revolving mirrors (J L Foucault and A A Michelson) a toothed wheel (H L Fizeau) or an electronically modulated light beam (E Bergstrand) also measured the time required for light to traverse the distance between a source and a reflecting mirror These are all group velocity measurements and furnish a value of c only if the experiments are carried out in a nondispersive medium in which the velocity is the same for all wavelengths Otherwise the group velocity is smaller than the phase velocity by 0 007% (2 2 km/sec) in air 1 5% in water and 2 4% in ordinary crown glass *See* DISPERSION (RADIATION)

Determinations of the phase velocity which is simply the speed of the wavefront (*see* PHASE VELOCITY) are indirect and make the assumption that $c = \lambda f$ where f is the frequency and λ the free space wavelength of the electromagnetic radiation Most of the measurements of this type involve microwave interference in various forms E F Florman with two sources K D Froome in an apparatus similar to a Michelson interferometer L Essen J P Gordon and H M Smith in a microwave resonance cavity D H Rank and also E K Plyer determined c by calculation from microwave and infrared spectroscopic measurements of the ratio of cycles per second to waves per centimeter for a certain molecular rotation frequency The phase velocity can also be calculated from the ratio of electromagnetic to electrostatic unit A detailed description of these experiments is found in the bibliographical references

The measured magnitudes of the velocity of transmission and the phase velocity seem to be in reasonably good agreement among themselves possibly to a few parts in 10^5 However the experimental values determined by the two methods are at an admitted and disturbing variance with one another The velocity of light is not as constant as it is sometimes thought to be While according to the theory of special relativity the velocity of light will be the same in any frame of reference independent of its state of motion this is true only for frames of the same gravitational potential Conceivably local variations of the gravitational potential could lead to variations of the measured velocity of light although experiments for detecting these variations remain to be devised The effect of the gravitational potential at the sun's surface or at other points in the universe is quite appreciable compared with the precision of many measurements of c *See* POTENTIALS (PHYSICS)

Electromagnetic wave propagation Electromagnetic waves can be propagated through free space devoid of matter and fields and with a constant gravitational potential through space with a varying gravitational potential and through more or less absorbing material media which may be solids liquid or gases Radiation can be transmitted through wave guides with cylindrical rectangular or other boundaries the insides of which can be either evacuated or filled with a dielectric medium *See* WAVE GUIDE

From electromagnetic theory and especially from the well known equation formulated by Maxwell a plane wave disturbance of a single frequency f is propagated in the x direction with a phase velocity $v = \lambda f = \lambda\omega/2\pi$ where $\omega = 2\pi f$ The wave can be described by the equation $y = A\cos\omega(t - x/v)$ Two disturbances of same amplitude A of respective angular frequencies ω_1 and ω_2 and of velocities v_1 and v_2 propagated in the same direction yield the resulting disturbance y'

$$
\begin{aligned}
y' &= y_1 + y_2 \\
&= 2A\cos\tfrac{1}{2}[(\Delta\omega)t - x\,\Delta(\omega/v)]\cos(\omega t - \omega x/v)
\end{aligned}
$$

Here $\Delta\omega = \omega_1 - \omega_2$ and $\omega = \tfrac{1}{2}(\omega_1 + \omega_2)$ The ratio $u = \Delta\omega/\Delta(\omega/v)$ is defined as the group velocity just as the ratio $\omega/(\omega/v)$ is identical with the phase velocity In the limit for small $\Delta\omega$ $u = d\omega/d(\omega/v)$ Noting that $\omega = 2\pi v/\lambda$ $d\omega = 2\pi(\lambda\,dv - v\,d\lambda)/\lambda^2$ and $d(\omega/v) = -2\pi\,d\lambda/\lambda^2$ an important relation between group and phase velocity is obtained

$$u = v - \lambda\,dv/d\lambda$$

This shows that the group velocity u is different from the phase velocity v in a medium with dispersion $dv/d\lambda$ In vacuo $u = v = c$ With the help of Fourier theorems the preceding expression for u can be shown to apply to the propagation of a wave group of infinite length but with frequencies extending over a finite small domain Furthermore even if the wave train were emitted with an infinite length modulation or chopping would result in a degrading of the monochromacity by introduction of new frequencies and hence in the appearance of a group velocity Considerations of this nature are not trivial in measurements of the velocity of light but are quite fundamental to the conversion of instrumental readings to a value of c Similar considerations apply to the incorporation of the effects of the medium and the boundaries involved in the experiments Complications arise in the regions of anomalous dispersion (absorption regions) where the phase velocity can exceed c and $dv/d\lambda$ is positive *See* MAXWELL'S EQUATIONS WAVE EQUATION WAVE MOTION

Refractive index A plane wave front in going from a medium in which its phase velocity is v into a second medium where the velocity is v' changes direction at the interface By geometry it can be shown that $\sin i/\sin r = v/v'$ where i and r are the angles which the light path forms with a normal to the interface in the two media

rd g t lassic l elocity addit on theorem (ch as i n w k o do not pply to light) a ocity d ff re ce of 2 w ld b d tected u der ch cum tan es

N ly does the earth mo e in a b t arou d th n, b t it i c ed with the n the ga het rot ti t ward Cyg s with a l city of everal h d ed f k l mete per s cond d the ga itself is m ing with a h gh speed ts lo- cal spiral gr p Speed of hundr d and po bly tho ands f kil m te s per econd hould be de- te bl by m rem ts o a th in two rth o- al directi ass ming f our e that the e th motion is itself with espect t i rt al p ce or ed th t s h a pace has the phy cal me ning cribed to t. The u pe ted r lt of the exp i nt as th t ch eloc ty d ff ence ould be detected, that s, o r lat m t o could be d tected b pt l mea

The M h lso Morl y ppar tu (Fig 3) n ts f a h rizont l Mi helson i terfe m t r th it tw arm at right ngle (see INTERFER OMETRY) Th m rr r ar adj st d that the n tral b t light f g f lls n the os ha of the serving t lesc pe Th s d ates qual ty f op- tical phase, nd the ef e an equal ty f the tim s taken b th light be m t tr el f m the be m ing rf t ea h of th tw m rr rs nd back. Rotat f the nt r sy t m by 90 i d b an a gl s w ll a epet t o of th ex periment at n s t mes f the y r ll e f u d to leave the ce tral wh te l ght f ge d s ed In ge er tem nd pl c d d ting n ching in th time q ired by the l ght t t e th t arm f th i t f m ter wh n th i direct rel t e t th d e t f th e th s motion ar ried H d the e bee a d ffer c the loc t f l ght the tw d r t OM d ON the t arm o ld b f u equal l gth the m t l adj tme t F x mpl f th l ght t eled f ter in the direct n OM (n the a e ge g in back and f rth) then the c rrespo d g arm would ha e to be lon r so a t make the time f travel equal in both rms If the app tus w e tur ed thr gh 90 the h rt arm would take the place f th lon er m a d the fa ter l ght would now t avel in the shorte rm a d the slower l ght in the longe arm a n ticeabl fring displ cem t would but a tually does n t t ke pl ce

9 3 Michelson-Morl y pe m t

E tein theory ccou ts for th n ll esult by the s mple e planat on that no rel ti m ti be twee the apparat and the ob rver e sts n the xper ment N cha ge in me ed le gth h oc c ed n e the direct on a d b au the pr pa gat n of l ght is t pic no v l city diff nce nor detect n f rel tive m tion ho ld b ex pect d

G a t ti l a d eb l r d sh fts Two d ffer ent ki ds f h ft or d pla em t f pe t al lin s tow rd the red e d f the spe trum are b- erv d in p ctr g am take with tarl ght l ght f om nebul e O i the r b t ext emely g nific t gra tati al r d h ft or Ein tei hift whi h ha bee me red in m spect a f om white dwarf ta Th oth m h m w dely co ter d is the r d shift in pe t a f m neb l e u ally de bed as bei g c u d by a rad l Doppler effe t cha cte ing n pa si of the u erse"

The mo t f m s e mpl of th g a tat nal ed h ft th t ob erved in the p ct m of the o- lled d k c mpa n f S u Th i te e f th compa n w s p ed t d b F W B s l 1844 n the b s f a p rt bat n the mo- ti n f S b t beca e of ts we k l mi ty (1/360 th t f th un 1/11 000 th t of S u) t w n t b n d t l 1861 This mp o i a whit dwa f of m s mp able t th t of the n (0 95) b t h ing el ti ly mall d s f 18 000 km d th fa t t lly h gh d n ty of 61 000 times th t f w te Th c mp ni n h w a h ft t pe t al l nes rel t e t th es em t t d by S s t lf the h ft of 0 3 A for the B lm β l f hydr g wa el ably det rm ed by W S Ad ms

The n b l red shift s syst mati h ft ob- rved i the pect a f ll b la b t m red w th th c l um H nd K b orpt n l s D t n f b l ar d term ed ph t metr lly b m m nt f th r t n t es d it i f nd th t th w el gth hift towa d th red i w th th d t n f the neb l e f m th e rth (The rth d e t ha p i l g d p t f xp n f the i i d d l ed th t p t m wh t l ke th t f a man a wd whi h d pe g—e y i d id l i th wd w ll fi d h m lf t n eve i c e s g d t f m o f h n ighb) Th h g f w le gth w th d t ce h bee gi b F G H bbl

$$\Delta\lambda\ \lambda = 1\ 7 \times 10^{-} d$$

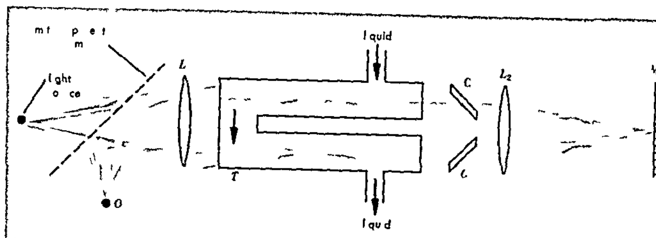


Fig. 2. Fizeau's experiment. C, compensator plates; M, mirror; L_1, L_2, lenses; T, tube; O, location of interference fringes.

rather is a description of the probability of occurrence in a given region of a given interaction or observation. See HAMILTON'S EQUATIONS OF MOTION; QUANTUM ELECTRODYNAMICS; QUANTUM FIELD THEORY; QUANTUM MECHANICS; QUANTUM THEORY, NONRELATIVISTIC; QUANTUM THEORY, RELATIVISTIC; UNCERTAINTY PRINCIPLE.

Relativistic effects. The measured magnitudes of such characteristics as wavelength and frequency, velocity, and the direction of the radiation in a light beam are affected by a relative motion of the source with respect to the observer occurring during the emission of the signal-carrying electromagnetic wave trains (*see* DOPPLER EFFECT). A difference in gravitational potential also affects these quantities. Several important observations of this nature are listed in this section, followed by a discussion of several important results of general relativity theory involving light. For extended discussions of both the special and the general theories of relativity, *see* RELATIVITY.

Velocity in moving media. In 1818 A. Fresnel suggested that it should be possible to determine the velocity of light in a moving medium, for example, to determine the velocity of a beam of light traversing a column of liquid of length d and of refractive index n flowing with a velocity v relative to the observer, by measuring the optical thickness nd. The experiment was carried out by Fizeau in a modified Rayleigh interferometer, shown in Fig. 2, by measuring the fringe displacement in O corresponding to the reversing of the direction of flow. If v' is the phase velocity of light in the medium (deduced from the refractive index by the relation $v' = c/n$), it is found that the measured velocity v_m in the moving medium can be expressed as $v_m = v' + v(1 - 1/n^2)$ rather than $v_m = v' + v$, as would be the case with a Newtonian velocity addition.

Aberration of light. J. Bradley discovered in 1725 a yearly variation in the angular position of stars, the total variation being 41 sec of arc. This effect is in addition to the well-known parallax effect and was properly ascribed to the combination of the velocity of the earth in its orbit and the speed of light. Bradley used the amplitude of the variation to arrive at a value of the velocity of light. Sir George Airy compared the angle of aberration in a telescope before and after filling it with water and found, contrary to his expectation, that there was no difference in angle. *See* ABERRATION OF LIGHT.

Michelson-Morley experiment. The famous Michelson-Morley experiment, one of the most significant experiments of all time, was performed in 1887 to measure the relative velocity of the earth through inertial space. Inertial space is space in which Newton's laws of motion hold. Dynamically, an inertial frame of reference is one in which the observed accelerations are zero if no forces act. A point in an orbit is the center of such a frame. *See* FRAME OF REFERENCE.

The rotation of the earth about its axis, with tangential velocities never exceeding 0.5 km/sec, is easily demonstrated mechanically (Foucault pendulum, precession of gyroscopes) and optically (Michelson's rectangular interferometer). The surface of the earth is not an inertial frame. In its orbit around the sun, on the other hand, the earth has translational velocities of the order of 30 km/sec, but this motion cannot be detected by mechanical experiments because of its orbital nature (*see* EARTH (ORBITAL MOTION)). The hope existed, however, that optical experiments would permit the detection (and measurement) of the relative motion of the earth through inertial space by comparing the time of travel of two light beams, one traveling in the direction of the translation through inertial space and the other at right angles to it. The hope was based on the notion that the velocity of a light beam would be equal to the constant c only when measured with respect to the inertial space, but would be measured as smaller $(c - v)$ or greater $(c + v)$ with respect to a reference frame such as the earth moving with a velocity v in inertial space if a light beam were projected respectively in the direction and in the opposite direction of translation of this frame. A

re cla i al theories that tt mpt to represent ectrom gnetism and gra t t a a pect of ace-tim g om try Alth h th re is some ex perim tal ev de c fo c t between elec m gn t m and gr t t th subject remain specul tive. F a d c s on of the better known unificat n pr po al *see* UNIFIED FIELD THEORIES also SPACE TIME [G W ST]

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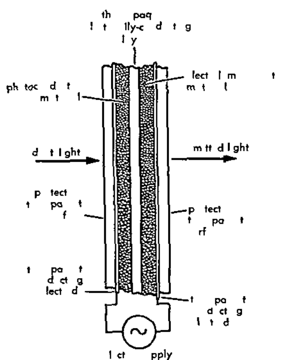
Light amplifier

An opti al electrical yst m th t rep odu e a d l ght d sce e with a gr tly r ed br l iance.

On system empl ys m d fi d t le is cam tube called a im g rth up n wh ch th d l lighted sc n i f n d The mag rth n changes th im g f th sc n nt a e f electrical impul thr gh a ep ted c g procedure on the fa e of th t b These mp l then greatly ampl fi d d tran m tted t a n p ct tube whe e b ill nt ew f ng l s d pl y d B htn ampl fi of the o d r f 40 000 ha b en cc m b d. S KI ESCOPE TELEVISION CAMERA TUBE t m b a b e d t h t em d s provement of th im ge e ult f m t le d e in a t n my a d f m fl op b th med c l p f A mod ficat n the im ge orthi n t ma e t f d ctly t x y p rm t l m t n of th fl o screen.

Another light ampl fi y t m c mbi e th pho- d ct ce phen m on d the le t l m scence phe men n s th t d mly l ghted e d n n de f thi e mble p d t imag (the e th pp te rf LIGHT PANEL) Th nc d t urfa e f th is co po ed f a l ye f ph t ond ti th b h h the p p rty f c nd t g p p rt to the de ty f the r d ed upo t Wh e the l ght ad t i the co d t n f l t rre t s gr t here the ad t l w th d ct on i

The trol m nes nt m t al h s th p p ty g l ght wh r ltern t g l tr t h g appl ed t a r t the mb ed h wn in th illu t t n a f dent l ght n th phot c d t g mat l of th t t l ltag t b ppl d th lectrol m sc t m t r al th d



S mpl fi d k t h f a l ght mpl fi (t t l)

n a a f l w de ty n id t l ht At tho p t whe e th in de t l ht de ty elat ely h gh th phot d t e m terı l p des a g od lec t cal nd t o p th d ss nt lly the f ll lt g of th s pply i pl d a r the lect l m nes nt m t rıal t th sp t (Th paq e h ld b twe n the l ver pe ce ly mall lt e dr p) C eq tly th s m te ıal will m t high dens ty f l ght t th p t At the a of the i d t e whe the dent l ght de ty s l ti ly l w th ph t c nd ct mat al pro- ide a m h p er nd tı n p th nd b b l ger f t n f th t t l pply olt ge C seq ntly l lta s ppl ed t the lect o- l m e t m ter l a d th den ty f em tt d l ht s l w t h s *S* ELECTROLUMINESCENCE PHOTOCONDUCTIVITY [W B B]

Light panel

A u f are l ght r th t empl y th pr ple f ele t lum sc e t p d c l ght L ht p el mp ed f tw h t f el tr lly co d ti m te l o a th n c d t g ba ki g d th th r t p e t d ct film pl ed n pp te d f pl t c ce m h et m p on ted w th ph ph h s zı c lfid a d m ll m nt f mp d f c pp ma g n Whe n lt t g ltag ppl d to th c d t e heet el t fi ld ppl d to the pho ph E ch t m th lect c fi ld h ge t d l dg el t f m th ed es f the ph ph ry t l A the lect f ll b k t th rm l t m t t th y ffe t th tom f th l ght mp t f oppe m g es a d d t f th w l gth f l ght m tt d (ELECTROLUMINESCENCE)

where d is in parsecs (1 parsec = 3×10^{18} cm) Red shifts in nebulae up to $1\ 1 \times 10^9$ light years distant have been measured in a comprehensive program carried out at the Mount Wilson Observatory by E G Hubble and M L Humason *See* Einstein shift Red shift

Results of general relativity The propagation of light is influenced by gravitation This is one of the fundamental results of Einstein s general theory of relativity which has been subjected to experimental tests and found to be verified Three important results involving light need to be singled out

1 The velocity of light measured by the same magnitude c independently of the state of motion of the frame in which the measurement is being carried out depends on the gravitational potential Φ of the field in which it is being measured according to the equation

$$c = c_0 \left(1 + \frac{\Phi}{c^2}\right)$$

Here $\Phi = -GM/R$ where G is the universal constant of gravitation ($6\ 670 \times 10^{-8}$ cgs units) M the mass of the celestial body in grams R the radius of the body in centimeters and c_0 the velocity of light in a vacuum devoid of fields

For example the absolute value of the term Φ/c^2 is about 3000 times greater on the sun than on earth making the measurements of c smaller by two parts in 10 on the sun as compared to measurements on earth

2 The frequency of light emitted from a source in a gravitational field with the gravitational potential Φ is different from the frequency ν_0 emitted by an identical source (atomic nuclear molecular) in a field free region according to the equation

$$\nu = \nu_0 \left(1 + \frac{\Phi}{c^2}\right)$$

Spectral lines in sunlight should be displaced toward the red by two parts in 10 when compared to light from terrestrial sources

3 Light rays are deflected when passing near a heavenly body according to the equation

$$\alpha = \frac{4GM}{c^2R}$$

where α is the angular deflection in radians and R the distance of the beam from the center of the heavenly body of mass M The deflection is directed so as to increase the apparent angular distance of a star from the center of the sun when starlight is passing near the edge of the sun The deflection according to this equation should be 1 75 sec of arc a value which compares favorably with eclipse measurements of the star field around the sun in 1931 These measurements *indicated values up to* 2 2 sec of arc when compared with photographs of the same field 6 months earlier This most sensational prediction of Einstein s theory might seem less surprising today when the corpuscular photon character of light is widely known and when a Newtonian M/R^2 attraction might be considered to be involved in the motion of a corpuscle with the velocity c past the sun However application of Newton s law predicts a deviation only half as great as the reasonably well verified relativistic prediction

Matter and radiation The possibility of creating a pair of electrons—a positively charged one (positron) and a negatively charged one (negatron)—by a *rapidly varying electromagnetic field* (γ rays of high frequency) was predicted as a consequence of Dirac s wave equation for a free electron and has been experimentally verified I Curie and F Joliot as well as J Chadwick P M S Blackett G P Occhialini and others have compared the number of positrons and negatrons ejected by γ rays passing through a thin sheet of lead (and other materials) and have found them to be the same after accounting for two other groups of electrons also appearing in the experiment (photoelectrons and recoil electrons) Other examples of negatron positron pair production include the collision of two heavy particle a fast electron passing through the field of a nucleus the direct collision of two electrons the collision of *two light* quanta in vacuo *and the action of a nu*clear field on a γ ray emitted by the nucleus involved in the action

Evidence of the creation of matter from radiation as well as that of radiation from matter substantiates Einstein s equation

$$E = mc^2$$

which was first expressed in the following wc If a body [of mass m] gives off the energy the form of radiation its mass diminishes by $E/$

In regard to exchanges of energy and momentum electromagnetic waves behave like a grou particles of energy

$$E = mc^2 = h\nu$$

and momentum $p = h\nu/c = h/\lambda$

Finally many experiments with photons that they also possess an intrinsic angular mon tum as do particles Circularly polarized light example carries an experimentally observable angular momentum and it can be shown that un certain circumstances an angular momentum be imparted to unpolarized or plane polarized li (plane wave passing through a finite circular ap ture) In any case the angular momentum will quantized in units of $h/2\pi$

The inverse process to the creation of electi pairs is the annihilation of a positron and a ne tron resulting in the production of two γ quanta (two quantum annihilation) Nuclear ch reactions are known to *in ol e similar pr ce* *See* Chain reaction Nuclear Elementary pa ticle Inertia of energy Pair production (electron positron)

Unified field theories In conclusion one mig m ti n the so-call d unified field theori The

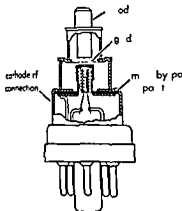


Fig. 1 Lighth se t b c t w y d w g (K R ...erb rg V cu m T b McG w H ll 1948)

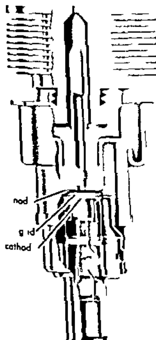


Fig. 2 Med m-p w lighth t be w th pl t t larg nd (G l El ct)

...t It w ld th seem mporta t th t th n ...ertio t th t l ct odes f th t be be l...ght t h w th t they be d ly ...rp ted t t rn l t es

These d ll es lt h be h eved w th th t ct f F g l wh h h w ly f rm f lighth t be Th t be t l a pl -eler t fig t f th t port n f th t be l t k lt w th t t be pl gged t t d bl c ent ll t t r Th l ad l ct es ed ed bee th nd t f th ...l q ency t ent a d k wh h th rrent fl w i f th most p rt d l Th ter lect od p ity i also ed ed t m m m.

A later fo m f tube ı hown n Fig 2 In this t be the anode ıs t the ba e of the lighth e and th cath de ıs at the small dıameter e d whı h ı ju t oppo ıte t the t tion ın the pre ı figure By th means the heat-dı sipation capacıty of the a de can be ıncre ed The t b shown u e a ce ramıc rather than gla cyl der between the dı ks connected to the ele tr de This pr ıdes a metal cer m c l p whı h t naturally m re rugged th gla s Metal ceramıc tubes are al o capal le of p ratıng at h gher tempe t es nd the ef e have g te d p tı d p w pa t y f g n *See* VACUUM TUBE [KRS]

Lightning

The larg park l ht p od ced by an abrupt d t s dı charg of el t c ty through th a r g lly de tu bulent co d t o of the at m phe e

C m l mbus clouds wh h produce l ghtnı g t n tro gly ı pw d m ng aı nd freque tly e t d t ltitude h he than 40 000 ft W thın th e cl d ı s fact r t to ca the ea t d ep ratı f ele trı h rge Confl t ng theor es ha e l en p op d t e pl n th ele t fi atı H we er th y ll l e lo d a d pr p t t part l nd l d t e tually the me h ge d t b t The upp part of thunde t rm p tı ly harg d wh eas the c tral nd l w p rt re p edom ntly neg tive I m l ud afte ra h f rm d sm ll p ıt e h g ce t ıs f d th l w p rt f the l d

Whe l d l ct fi tıo ha proceed d t the po t wh th p te t l gr dıe t betwe n adja ent h g enter or betw n the l d and gro d h the b kd wn lu the large p rk c lled l ght g s A br kd w pot nt l f bout 10 000 lt /cm h been gge t d as n appro- p te l e f a r t nı g wat d plets

It h been establ h d that l ghtn g tr ke t gr d ı nt ted by a tep l d r A s rge f le t m es d wnw d abo t 50 m n bo t l μ ec d th n t p Aft p u e f pe h ps 50 μ th t p t k pl Th eq e ce r pe ted t l the le de r hes the gr nd Wh n th oc u a rge f h g m es rap dly p the p th tak l y th t p l der Wherea th a ag peed f th tep l d ı f the ord of 10 m/sec th m n tr k mo e p th p ı nzed p th t peed f th d r of 10 m/ ec Th l m os ty l th o-c lled eturn tr k ı qu te t

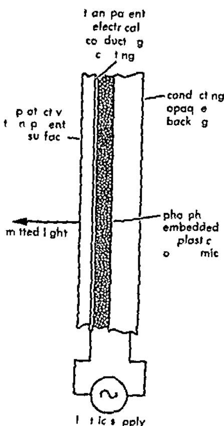
After n ınt rval of the o d r of 0 01 se an th r tr k u lly oc r th me chan l. These ec da y t rn t k e p ded by d wn ward m ı g dart l d r wh h d ot show t p h t t A ma y 30–40 t okes h e bee be rv d t occ r ı th ame han el

Cl d to-cl d t kes lso ı l a tep l ad d m n et rn t k

Th rr t f th r t rn t kes ı c es er g f bo t 6 ı t a m mum al f

In contrast to incande cent vapor di charge and fluorescent lamps which are e sentially point or line sources of light the ele troluminе cent light panel i e sentially a surface ource of light Com plete *freedom of size and shape is a fascinating* aspect of lumine cent cells

Brightness of the panel dej end upon the voltage applied to the phosphor layer and upon the electri cal frequency In general higher voltage and higher *frequency both re ult in a brighter panel Blue* gre n red or *yellow light can be produced by* the choice of phosphor and the proper blend of the e colors produces white light Color can be varied for a particular pho phor by changing the frequency *of the applied voltage Increa ing the frequency* hifts the color toward the blue end of the spec trum

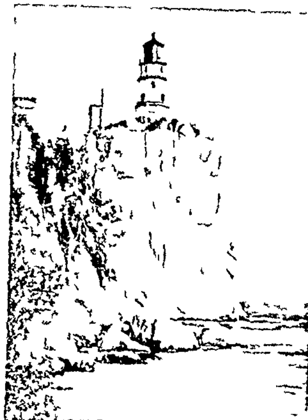


S mplif ed sketch of an electrolum nescent cell (not to scale)

The efficiency of the e light panels is only a frac tion of that of the mo t efficient fluorescent lamps *Theoretical limits indicate however that the effi* ciency can be further improved prol ably to ex eed that for flu re cent lamp Becau e panel lights em ploy no filaments and no evacuated or gas-filled bull s replacement of units is irtually eliminated *Glarele s uniform di tribution of light fr m* large area sources is po sil le without shade k uver or other control devices *See* ILLUMINATION [W B B]

Lighthouse

A distinctive structure built on or near a h re which exhibits a light of distinctive charactert tic to erve as an aid to navigation Le er ligl t may



Lighthouse on a coastal headl nd (U S Co st Gua d)

be displayed *from fixed structures called beac ns* or from floating l uoys or lightship

The characteristics of the lights di played l y lighthou es are given in *light lists available* to mariners and in abbreviated form on charts S me lights have one or more sectors in whi h the light appears red usually to warn of some danger in this ector *In other sectors most lights are white*

Lighthouses have been diverse in structure and type of light Towers up to 200 ft were c n tructed along the Mediterranean coa t of Egypt many cen turies before Chri t with beacon fires maintained by prie ts Logs coal oil gas and finally elec *tricity have l een used to provide lights An* at tendant is continuou ly on duty at many light hou e l ut some are unattended and ome recent in tallations are ontrolled remotely from a con venient l cation *See* PILOTING [A B M]

Bibliography U S Coast Guard *Aids to Navi gational Manual* CG 22? 1950 N B wditch *American Practical Navigator* U S Navy Hydro-graphic Off ce H O 9 1958

Lighthouse tube

A special type of tri de developed to operate at very high frequencies A limitati n f c nventional tul es f r operation at high fre juencie occur be cause of consideral le circuit *imj edan* e a ociated with the wire lead that are attacl ed t the elec tr des *The e wire individ ally have con iderai le* *self inductance* and there i al con iderable tray apacity l etween tl em In ad litic n the m t effcient circuits f r op ration at tl e ultra high frequencie are cavitie rath r tl an lump d cir

od
g d
athod rf connection
m by p po t

Fg 1 Lghth se t b t w y d w g (K R Sponenb g V m T b M G w-H ll 1948)

nod
gnd
hod

Fg 2 Med m-p w lighth t b w th pl t t large nd. (G I El t)

nt It ld th n eem import t that th co
sectin t th a t el ctrodes f th tube be
brought t h wa that th y c n b e dly
incorpor ted t xte l t es
These des abl res lts h e b ch e d w th
th struct f F g 1 h h sh w an ea ly f rm
light t be Thi t be ut l ze a pl ne lec
t fig at n f th acti porti n f th
d b t f b lt so th t it c n be pl gg d i to
t ent c ax l l ne t t r Th le d
ind ners ar rd ed becau th d t
the r d of equency t d k wh h
current fl w i f the m t p rt r d l Th
er lectrod ap ty is l d ed to

A late form of tube hown in F g 2 In this tube the anode is t the ba e of th lighthou e and th cath de is at the m ll d amet r end whi h i ju t opp ite to th situ t on n the prev us figu e By this mea s th heat di pation capac ty f the an de c n b incr ed Th tube hown u a ce ram c r ther than glass yl der between th di k connect d to the lectrodes Th s p ovide a metal ce am c e elope wh ch s naturally m e r g ed th n gl ss Metal cerami tube ar l o pable of ope ti at h ghe temperature and ther for ha a gre ter d ip ti and power capacity f r a g e siz *See* VACUU I TUBE [K R S]

Lightning

The l rg spa k l ght p od ced by an abrupt di c ntinuous d ch rge of le tri ity through the gen lly u der turb lent c nd t ns of the at m pher

Cumul imbus lo ds wh ch p d ce l ghtn g t n tr ngly upward mov n ai nd frequently e te d t alt t de hi h r tha 40 000 ft With n th e lo d ri us fact r ct to u e tl e rea t n and separ ti of el ctr c ch rge Co flicti g the es ha been prop d t e pla n the electri ficat o H we er they ll n l e cl ud and p e c pit t o p rti le nd le d to e e tally the s me cha ge d t b t n The uppe p rt f th d r st rm a e po t ely ha g d whe ea the e tral d lowe pa ts ar p ed m nantly neg ti e In ome lo d aft r ai h f rm d a mall po it e harge e ter i f nd i the lower p t of the l d

Wh cl ud el ctrifi ati n h p o eeded t the p i t wh e the pot nt l grad e t between adja e t charg c nte o b twee the l d and gr und r che the b e kdow al e th l ge spa k c ll d l ght o u A b eakd wn potent al f abo t 10 000 lt /cm h s been s g ted as n app o-pr at l fo a o tai n w te d plet

It ha b n t bl h d th t l ght g t oke t g d ti ted by a tep l ade A g f ele t s mo e d wnw d abo t 50 m in about 1 μ d th n top Aft pa e of p h ps 50 μ e other st p take pla e Thi eque e i r peated u til th lead r a hes the gro nd Whe th o u s g f h ge m es p dly up the path t ken by th st p l ade Whe ea the a e a pe d f th t p le d i f the rde f 10 m/ e the ma t oke mo e p th p e n ed p th t a pe d of the d r f 10 m/ ec Th l m ity of th o- alled etu t k s qu te i te e

Afte i terv l f the rder f 0 01 ec an th r t ok lly c urs n th s m ch nnel These c d rs eturn tr ke r p e ed d by down w rd m g d rt le d r wh ch d not how st p har t r t A ma y as 30–40 t ok h been h erved t uri th m h nel

Cl d to- l d tr k al o m l e tep l ad d ma turn t ke.

Th r t the t rn trokes i re es n an a e ge l abo t 6 μ t m im m al fre-

quently exceeding 30 000 amp but sometimes as high as 200 000 amp It decreases to about one half the maximum value in an average of about 24 μ ec Average currents during the strokes are of the or der of 10 000 amp and about 500 amp may flow through the ionized channel in the interval between strokes A reasonable estimate of the diameter of the channel appears to be about 10 cm The high currents lead to thunder and are mainly responsi ble for the damage caused by lightning

See ATMOSPHERIC ELECTRICITY CLOUD PHYSICS TERRESTRIAL ELECTRICITY THUNDERSTORM

[L J B]

Lightning and surge protection

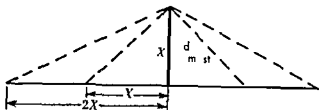
Means of protecting electrical systems buildings and other property from lightning and other high voltage surges

The destructive effects of natural lightning are well known Studies of lightning and means of ei ther preventing its striking an object or passing the stroke harmlessly to ground have been going on since the days when Franklin first established that lightning is electricity (*see* ATMOSPHERIC ELECTRICITY LIGHTNING) From these studies two conclusions emerge (1) lightning will not strike an object if it is placed in a grounded metal cage and (2) lightning tends to strike in general the highest objects on the horizon



F g 1 Inst llation of l ghtning rod on a home

One practical approximation of the grounded metal cage is the well known lightning rod or mast (Fig 1) The effectiveness of this de ice i evalu ated on the cone of protection principle The pro tected area is the space enclosed by a c ne having the mast top as the apex of the cone and tapering out to the base Laboratory tests and field experi ence have shown that if the radius of the ba e of the cone is equal to the height of the mast equip ment inside this cone will rarely be struck A ra dius equal to twice the height of the mast give a cone of *shielding* within which a hit will occasion ally occur The cone of protection principle is il lustrated in Fig 2 *See* LIGHTNING ROD

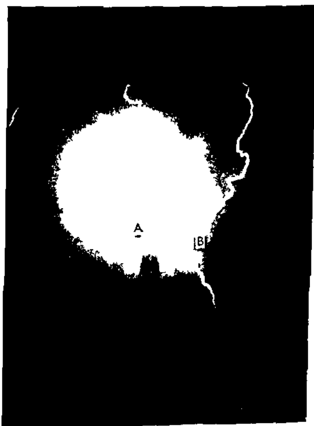


F g 2 Cone of protection of a l ghtning rod or mast

A building which stands alone like the Empire State in New York City is struck many times by lightning during a season It is protected with a mast and the trokes are pas ed harmle ly to ground It is interesting to note however that lightning has been observed to strike part way down the side of this building (Fig 3) This shows that lightning does not always follow the paths pre scribed for it by man but will occasionally dodge the protective devices provided

The probability that a building will be struck by lightning is considerably less if the building is lo cated in a valley Therefore electric transmis sion lines which must cross mountain ranges usu ally will be routed through the gaps to avoid the direct exposure of the ridges

Overhead lines of electric power companies are *vulnerable to lightning* Lightning appears on the e lines as a transient voltage which if of sufficient magnitude will either flash over or puncture the weakest point in the system insulation



F g 3 A m lt ple l ght i g t oke to Empi State Bu ld g a d e rby b ld ng A g 23 1936 B si gle cont n ng l ghtn g st ok to Empi St te B ld i g Aug 24 1936

Many of the troubles that cause service i ter ruptio s on electr cal systems a e the res lt of flashovers of in lation. N perm n nt damage h s been done at the po nt of f lt, and ervice an be restored as soon as the c use of th trouble has dis peared. A puncture f the insulatio on the other hand, requires rep ir wo k and damaged apparat s mu t be removed f om serv e

Th re are a numbe of p tecti d v ce to l m t or preve t l ght ing d mag to ele tric power sy tem a d equipment. Th w rd p tecti e s u ed to conn te ithe ne or tw f ncti th p even tion of tro bl o the l m ati n of t after t oc cur Various p otect e mea h e been devi ed eith r to p event l ghtn ng f om e tering the y tem or t d ipate it h rmle ly if it d e

Overhead ground wires and lightning rods These devices are used to prevent lightn ng from striking th lectric l ystem

The gro ded m tal-cage prin ple app ached by overhead gr und wi es, pref rably tw n stalled over the t a mis n pha condu tor and gro nded at h towe The gro nd wir must be pr perly located with re pect to the ph e con

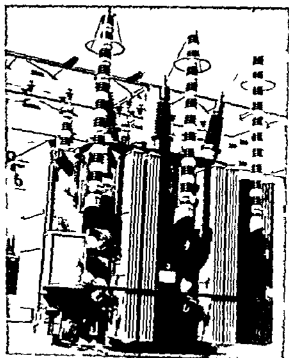


Fig 5 l toll t of th Ge l El ct Co Thy t t on-cl ss e t t d 121 kv l ne-to-g o d p ot ct g 115-k d f 20 000 kv th ee-ph se p we t o f rm

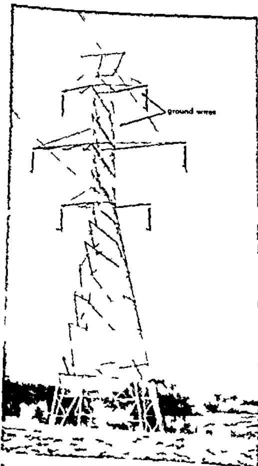


Fig 4 Do ble-c suspe ion ow the Olive-Good ng G ov 345-k tr sm io l ne w h tw cuits ng nd w th tw ground wi s. (I diana nd Michig Ele ic C Ame ica Electric P w C .)

du t r nd h dequate cle rance f m them both at tl e tow and through ut the sp n If towe footing res t nces e too high they must be l w red t ac ptable al es with dri e gr u d ods with bu d counte po es The lightning stroke curre t m t ha e a s ffic tl low imped anc p th to gro nd so that the ltag alo g this path t h gh e gh to fla h l ack to the l ne ndu t rs (F g 4)

Th gr u d wir s are ften brought in o the t rmin l ub tations F add ti n l shi ld g of the s b tat n l ghtn ng rods r i talled Sev e al d r ally u ed to obta n the de ed p o-tect n.

Lightning arresters These prot tive de-es f edu ing the t n ent y tem rvoltag s t lev ls c mp t ble with the term l ppa tus n ul tion They con ected i pa allel with the pp tus t be pr te ted One nd f the rrest s ground d a d also b ded t the e of the equ pm nt be ng p otected th otl er end is nected t the lectric condu t r (Fig 5)

V l e-type arrest rs p de a lati ely low d s-ha g path t gro d f the tr n ient erv It age and a rel t ely high res ta e t th p we y tem f ll w rr nt so th t the perat n does n t use a sy t m h rt c t

In sel t g rrester to p tect a tr n forme f r ampl th ltage levels that a be m t i ed b th reste both on swit h ng urges nd l ght g u ges m t be coordinated with the with t d t gth f th tra sf rmer t thes urges Arrest g p park-o r v ltages d scha g It

ages on various magnitudes of discharge currents arrester lead lengths and other factors must all be evaluated See LIGHTNING ARRESTER

Rod gaps These also are devices for limiting the magnitude of the transient overvoltages They usually are formed of two ½-in square rods one of which is grounded and the other connected to the line conductor They have no inherent arc quenching ability and every operation is usually associated with a system outage

These devices are applied on the principle that if an occasional flashover is to occur in a station it is best to predetermine the point of flashover so that it will be away from any apparatus that might otherwise be damaged by the attendant short circuit current

The flashover characteristics of rod gaps are such that they turn up much faster on steep wave-front surges than the withstand voltage characteristics of apparatus with the result that if a gap is set to give a reasonable margin of protection on slow wave front surges there may be little or no protection for steep wave front surges Also the gap characteristics may be adversely affected by weather

Rod gaps will limit transient overvoltages They have no inherent arc quenching ability and once becoming conducting they continue to arc until the system voltage is removed Since each operation is a system outage they should not be considered an arrester

Immediate reclosure This is a practice for restoring service after the trouble occurs by immediately reclosing automatically the line power circuit breakers after they have been tripped by a short circuit The protective devices involved are the power circuit breaker and the fault detecting and reclosing relays

This practice is successful because the majority of the short circuits on overhead lines are the result of flashovers of insulators and there is no permanent damage at the point of fault The fault may be either line to ground or between phases Reclosing relays are available to reenergize the line only once or three times with adjustable time intervals between reclosures

If the relays go through the full sequence of reclosing and the fault has not cleared they lock out If the fault has cleared after a reclosure the relays return to normal

Permanent faults must always be located and removed from a system and the accepted electric protective devices are power circuit breakers and suitable protective relays See CIRCUIT TESTING ELECTRICAL ELECTRIC PROTECTIVE DEVICES

[E M H]

Bibliography American Institute of Electrical Engineers *Revised Report on Standards for Valve and Expulsion Type Lightning Arresters* AIEE 28B 1956 E Beck *Lightning Protection for Electric Systems* 1954 W W Lewis *The Protection of Transmission Systems Against Lightning* 1950

Lightning arrester

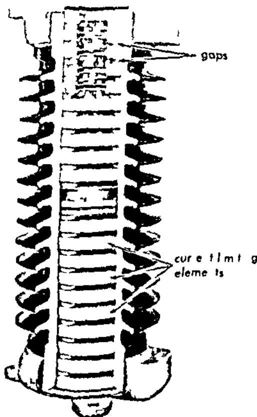
A protective device designed primarily for connection between a conductor of an electrical system and ground to limit the magnitude of transient overvoltages on equipment

The valve arrester consists of a single gap or multiple gaps in series with a current limiting element The gaps between spaced electrodes prevent the flow of current through the arrester except when the voltage across them exceeds the critical gap flashover They reseal when the voltage returns to normal The current limiting (valve) element reduces the current flowing through the arrester and aids the gaps to reseal

The current limiting element is a nonlinear resistor whose resistance decreases substantially as the voltage across it increases

Other types of arresters called expulsion arresters have spaced electrodes in an interrupting chamber which contains gas evolving material

System overvoltages may be of either external or internal origin that is lightning or switching The arrester is unable to determine the origin of the overvoltage and must attempt to limit the magnitude of all abnormal voltages above the gap sparkover voltage Hence a lightning arrester is really a voltage surge arrester



Thr e k (gap spa k lt ge) Thy te m g l t t -cla s l ght g a rest r ted 60 kv d cha g oltage Cut-away ect o h w mag et gap struc tu betwe n paced lect odes a d cu e t l m tl g l m ts (Ge al El ct i Co)

I portant appl c t on characteri t cs of ar re ers a e (1) gap sp rkover (n rmal f equen y a d m l e) (2) gap re eal volta e (maximum perm ble rmal f eq e cy olt g ac os the reste) (3) d ch ge lt g a ro the arr t r (al type) du ng pa age of rr nt, and (4) d ha g apabil ty

The gap spa ko er oltage and the d scha ge lt g h r cte t c det rmine the maximum tr t ltag le el perm tted by the arreste They a e the meas res by whi h the protecti e ef f ency of arrest s d term n d The d cha ge apabil ty s th m a u e of the ar e t r end an e k sev el ht g nd sw t hi g rge

Arrest rs a e l fied a tati ntermed ate or d trib t n Stat n-cla arreste a e al e arrester ed for the p ote t n of apparatus n mport nt ub t ti wh re th m t effi ie t pro- tection s desired I term d ate I r te s als *I et pe a e used* for the pr te ti n f ppar t m m ll a d med m ub tation wh e o- a m n d r tion d not ju t fy the u f t u n type ar e t s D tr b t n cla a re t r may be dher l o pul i n arre t rs nd ar u ed f the p tecti n f p le type d tribut on ppa r t p p lly d str but n tran formers

[E M H]

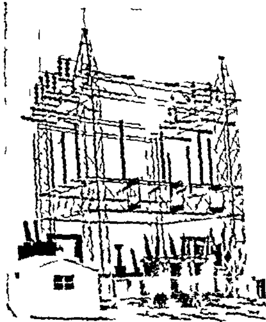
B bl o phy Am r ca Sta dard As oc t on *Ligh g A re t s fo Alt nating Cu t Powe Ci uts* ASA Sta dard C62 1 1957

Lightning rod

A met ll c rod set up on an xp d levat on f stru t nd on ected t low hm c ground to intercept and t pr ide a direct c nd ct ng path to gr und f r li htn n dı harg s that might other w se damage the st uctu e be ng p otected Light n ng rod a e al o called lightning ma t

The ffecti ene s of the protecti n obtain d de- pen ls upon (1) s ffc nt l e ght of the ai term nal end of the r d f the lightn ng stroke to ter minat on it rath r than n the p otected t i t i (2) suffic ent c d cto (rod) cr ss ecti n to ca ry th h htning tr ke curr nt t gr und and (3) a low re ta ce g ound onn cti n S e LIGHTNING AND SURGE PROTECTION

[E M H]



Ou door b ion H dso R wo p mpi g a ion in Ch hso N w Y k Light l g od a lo- ated on he four hed m f h eel truct

Light year

A unit of mea u em nt of ast onomi al di tance A l ght yea is the d stanc l gl t tr vels in 1 s de- e l y a O e l ght year is eq i alent to 9 461 × 10 kil m te s or 5 879 × 10 m l s D ta ces to me of th ne r r el stial objects mea u ed in u ts of l gl t t me a e sh wn n the tabl

Obj t	D t from Ea th (l gl t t m)
Moo (m)	1 3 sec
Su (m)	8 3 m n
M rs (losest)	3 1 m
J p t (losest)	33 mi
Pl t (losest)	5 3 h rs
N rest ta (Proxim Ce t)	4 3 y rs

Th un t wh le u eful fo ts g phi p ta ti f th n rm u ale f tell d t c is eld m u d t chn cally S e ASTRONOMICAL UNIT PARALLAX (ASTRONOMY) PARSEC.

[J L CR]

Lignite

Th nam of th t g oup f c n olidated l gnitic c al with a heat v l e le than 8300 Btu/lb on a m t m ne al m tter free b sis Unc ol dated l gn t oal a e alled b wn co ls ex ept n Eu r p wh r all l gn t c als a de g ated a brown coal *The brown coals* f G rm ny wh they re p rti ul ly imp tant, ha e l e cl fi d a soft a d ha d The s ft b own o l a e cl s fi d a rthy d f l a eo the hard a d ll (m tt) d bright (glance) c al Th gl nce br wn coals r bl k l g co p nd t b t m n al f cla s C. S e COAL.

O er 9 f l gn te n the U ted St t i n the n rth c tr l tate p c p lly in No th d South Dak ta d Wy m ng in the F t Un n (Paleoc) fo mat n All *but a fract* n of 1 f th r m nd i in T xa The tot l erve s n the ord 463 × 10 t n Th ma n u f lig t n the Un t d States i t comb ti n f r th p d t n l heat and pow Lign te u d t any gr at di tan f om th p nt f r g no m lly eq es d hydrat o and b quet g M n g u ually l y ope t o t pp g m thod

[C H C]

Lignumvitae

A tree *Guaiacum sanctum* also known as holywood lignumvitae which is cultivated to some extent in southern California and tropical Florida Lignum vitae is native in the Florida keys Bahamas West Indies and Central and South America It is an evergreen tree of medium size with abruptly pinnate leaves The tree yields a resin or gum known as gum guaiac or resin of guaiac which is used in medicine The very heavy black heartwood is used in bowling balls blocks and pulleys and parts of instruments Other species include *G coulteri* *G guatemalense* and *G officinale* See FORFST AND FORESTRY TREE [A H G]

Liliales

A large and important order of the plant subclass Monocotyledoneae arranged in 7 families with 427 genera and approximately 8000 species The flower parts occur mainly in 3s or multiples of 3 and the endosperm is fleshy One half the genera and species belong to the lily family (Liliaceae) of the warm temperate and tropical regions—the most representative monocot family Members of this family supply food (including asparagus onions and garlic) fiber and drugs many are prized as ornamentals

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Limburgite

A dark glass rich igneous rock with abundant large crystals (phenocrysts) of olivine and pyroxene and with little or no feldspar

The glass is brown and usually alkali rich Phenocrysts are well formed and the pyroxene shows zonal structure (diopsidic cores and titanium rich margins) Small quantities of feldspathoid hornblende and biotite may be present Granules of titanium iron oxide are abundant and widespread

Limburgite is a rare rock and forms lava flows and small intrusive bodies (dikes sills and plugs) It is associated with basanite and alkali basaltic rocks It probably originates from basaltic magmas and lavas by accumulation of olivine and pyroxene crystals under the influence of gravity Thus limburgite may grade through oceanite to basalt *See* BASALT IGNEOUS ROCKS [C A CA]

Lime (botanical)

An acid citrus fruit *Citrus aurantifolia* usually grown in tropical regions because of its low cold resistance The two principal groups of limes are the West Indian or Mexican and the Tahiti The West Indian lime is a small tree with irregular branches having short stiff sharp spines The fruit is small (walnut sized) and strongly acid It is more sensitive to cold than the Tahiti lime which is a more vigorous tree bearing fruits of lemon size



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Limes are used in frozen sherbets and in beverages such as ades and in alcoholic drinks The juice has many culinary uses such as flavoring in jellies jams marmalades and as garnishing for fish and meats *See* FRUIT (BOTANY) FRUIT (TREE) [F E C]

Lime (industrial)

A general term for the various products of calcined limestone for example quicklime and hydrated lime Principal uses of lime are in mortar stucco and plaster for the building industry as a flux in the metallurgical industry as a refractory for lining open hearth furnaces as addition to soils either for agricultural purpose or to stabilize roadbeds as a chemical raw material as in the production of glass and also in water purification sewage treatment pulp and paper production

suga refi ing, petr le m refini g and t nning

Limest es a e cla fied a rding to the r mag nes m conte t h h-calci m lime t nes have less than 5 by e ght (% wt) magnes m carbonate and magnesia limest nes ha e er 5% wt when the sto e co tains bet een 30 and 45% wt mag nes m carbonate it is k own a dol m tic lime st ne Dolom te tself is m eral of mixed calcium and magnes m carbonate rr spond g to the formula $CaMg(CO_3)_2$ r ab ut 46% wt $MgCO_3$ Th high-c lcium nd d lomiti lime tones are the importa t sou ces of lime the esulting l mes re co espondin ly amed

Limest e ($CaCO_3$) is alc ed in vertical shaft kil t drive ff th ca bon di xid th resulting product qu kl me b ng mad up of cal ium x d (CaO) w th s me magne um ox d (MgO) Qu klim is u ed a n h but oft n t is treated th te t f rm hydrated l me $Ca(OH)_2$ The p oces f hyd at on i kn wn a laking but g n rall the term l ked lime is used t designate the material w th x ess wate e th t n eded t form the h dr x d Hydr ted lim i dry powde sl ked l me a paste o putty M lk-of l m is hy d ated l m su pe s o nd ol t on n wate

H d a l c l me is mad from a l mest ne on ta n g l a and al m na wh h wh n th tone s cal med t a t mpe atur just hort of f on f rm anh d ated calcium alum num l ates wh ch al low th materi l to set u der water *See* PORTLA D CEME T

H h-c l m hyd ated l mes c n t t lly of $Ca(OH)_2$ but d l m t l mes hyd ated n the orm l f hi n (t atmo ph ric pr re) ntain co ide bl amount of unhydr ted MgO Be e of tro bles au ed b th dela d hydr t n f th m teri l (f r exampl popping f pl ster m d with d l m t l m) it h b me the pr t e to p od c a peci lly hyd ated d l m t c l m by h d at g u der pres u

Th phy l p perti f l me e affe ted by th co d t f le n t n nd hydr t on Fo ex mpl d adb rned d l m te r a c e-gra ned h gh-tempe t e p od t w th l w rat f hyd tion, a d t i f l efr t ry *Se* FER PHUER KI N LI IESTONE PLASTE [I C M]

Limestone

A sed ment ry rock mpo ed d min tl f r bo at m r l p n p lly bo tes f c l m d m g esi m Limest es a th mo t b d t f th l t ock M h k wledge f e rt f r t p leo t l g d seq e tly of the ea l i f l l d rth h t ry comes from th fos l ta ed i them Alth gh th w d lime t n sed n th g r l se e bo e pec fi c ll t f t rbo t ock d m nated by the m l l t $CaCO_3$ a pposed t d l m t a t m f a bonat rock d m ted b th *m n al* d l m i $CaMg(CO_3)_2$ Alth gh the *m n ral* g l ompos t n f most l mest es i m l th r t at ea t f r they m be f rmed u d a g t ety f co d tion S DOL MITE ROCK

Chemical composition The hemic l compo tion of limestones is l rgely calcium oxide CaO and c rbon dioxide CO_2 Magnesium ox de MgO i a common con tituent and if it e ceeds 1 or 2% the rock m y be termed magne ian limestone Sm ll amount f ilica and alum na may al o be present these are due t the presence of cla ti mate ial qu rtz, and clay Iron ox de m y b p ese t either as arb nat (der te ferr an dol omite) or in other mineral h as clay Stron tium (Sr) may be pre ent a an import nt trace element, probably d i ed f om or g nal fossil ma terials n whi h it was in orpor ted into aragon te form of $CaCO_3$

Mineralogy The chi f mine ls f limest nes are alc te nd ar g nite and n th d lomitic lime tone d l mite. Calc te and a agon te ha e the ame c mpos t on but b au their tru tures are different, arag ite is un table with refe ence to alc te in earth urf ce en ir nment and will b tran f rmed int the latt r with t me F en though ar gon te s unstable it f rm as a p e ipitate from a water both in rg n c lly as ool tes and biogenically through the intermediate mech ni m of b ologic l se et n by hell form ng rg n ms. The co of agonite to calc te is cc m pl hed in a elat ely sh rt time j st a few yea s f r ome f sils Ancient rocks alw y ont in al cite rather than r g nite

Dol m t altho gh t seem t be stabl in earth su fa e environments i f rm d as a primary p ec p t te only unde pecial ndit ons su h as high alinity or high alk l n ty Petrograph c evi de ce gge ts that mo t d l mite i formed post dep s ti ally by the inter ti n of magnesium i n in i t rst t al waters w th alc t

S d r te the i on carbon te i found *in ome* limest nes, but iron occur in carbonate form ch efly as ferr an-dolom te S l ca may be *present*, ther fi ly d em n t d th ughout *the rock o* greg ted int n d les of ch rt. Silica al occurs a mall cry tal th t *have gr wn in place* duri g diag nes Feld p r occur *in the same way* but i les common than l Oth r min r ls found in limest es are gla c te coll phane and pyr te A h t f oth min *als may be* f u d as mall mount of l stic mat ri l brought in by current includ ng alm t alw y a sm ll m u t of fine gr i ed clay Orga ic matter may also b f u d *Se* DIAGENESIS

Textures *Th* text res of lim t nes eveal much abo t the *o gin Th* hief t xtur l l m nts in a great many l mest nes are fo il wh l or fr g me tal The species r presented are a gu d to th ec logy *nd* n onme t f the ite of d posi t l dd tion, th natur of th fo il deb is wheth r complet art ulated hells o fragments in all tages f d arti lat n nd fragm tat n is g id to th presenc of *bott* m urrents that may h t ansported the fo il fr m place to pl ce on the bott m

Som mechan lly depos ted l mestones show w ll sorted p rt les f c lcite cem nted by cl ar

Lignumvitae

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Fig 1 V lt ge-c rr t ch ct t f j ct d d

current ch te t f typ l s m du t d d h n t F 1 In the fi t qu dra t th charater t c t th t f th f rw d b ased d de Here th h t tic may be pp mated by a linea es ta f a l w l Thi alue m ght range from a f w hm f m j t n d od t sever l h d ed ohm fo a typical cuum t b diod In th th d q d ant r b as r g n the chara teri t c m y be pp im t d by x tre l l ge lin re t e t l the dd n le k r th ct ty f V o e r At th po nt known th Ze br kd w lt g th rr t beco es e t llv depend t f lt e (SEMICONDUCTOR) Eith th sh p tra t n that occurs h g g fr m th r e-to-f rwa d b cond tio r th Ze e eg m y b d f l m ting

Th se f both cha ct ti m ltaneo ly is illust ted in F g 2 The p t mpl tud f th tput wa fo m is lim ted pp mat ly at the fe nce ltag *V* and th n g ti e mplit de s l mited t a l el $V - V_B$ o e pond t the b kd wn volt ge f magn t de V_B Sh p l m ting in th forward b s d ction s a h eved when the forward ist e R_f m ll compared t the e ver e-b re tance *R* wh n R_f sm ll c m p red t *R* a d wh any sh nting l ad tanc *R* l rge mp d t R_f

Th ac m d d may b used a l m ter u ing the forw rd r e b reg o but t has no u ful b e kdown m l to the Zene egion f the ju ct n di d If ther p t e o gati e l miting eq d ther va uum o micond to d des m y be u d with th refe en olt d the d de p l ty e d If b d rection l l m ti g des ed the cir u t of F 3 may be u ed w th tw d de nd two p ate b as lt a

M lt l ment le tron t b or t a t r al may be u ed l mite s G d c t l m t g of um tub s sh wn Fig 4 N rmally when ed n ampl fi the g d t e with e sp t t the th de nd th put es stan h h If th gr d b c m p it e w th p t t the th de g d re t flow nd the inp t re ist n is l w In th s p t, the gr d c th d c cu t f the tub b h es as uum d de w th th w f rm lim ted h wn The pl te c cu t t s t ampl fi t on p p t d th mpli fie pl t ltage w f m f the no l m ted p r t is t d h wn

Th t ti n ch t t f th tp t ci t of p t d a m tube o a comm n m t t t n t r m v al b u d t bt n limit g The t f h de ce a d the tput ch c t ti wh ch m y b ppl d t the de e h w n Fig 5 F th p nt de the f mily of

Fg 2 C b ed se-b d Z b kd w l m t g

Fg 3 B d chonal l m g g tw d od

intergranular calcite If the particles are and size the rock is termed calcarenite In general the me chanically depo ited limestones show the same kinds of sedimentary structures as do clastic rocks Cross bedding tratification current linea tion and even graded l edding may be di played Oolitic and pi olitic textures are most abundant in limestones *See* OOLITE AND PISOLITE

Secondary textural features that are found in limestones include stylolites (cross cutting veinlets filled with calcite) and replacement effects (typi cally that of rhombohedron of dolomite replacing calcite) Be ause the carbonate minerals are rela tively soluble in aqueous solutions and becau e of the transformation of aragonite to calcite and cal cite to dolomite recrystallization and other dia genetic effects are particularly common in lime stones *See* STYLOLITES

Classification Limestones are divided into two major groups the autochthonous and allochtho nous The autochthonous limestones have been formed in place by organic or biogenic precipita tion from the water of the environment usually ea water the allochthonous have been transported from the site of original precipitation the deposi tional agent primarily responsible being current action The total distance of transport of allochtho nous particles may not be great the transportation is mainly a process of moving a chemical precipi tate from one part of a sedimentary basin to an other Carbonate minerals of sand or finer sizes are rarely found in surface streams and river for they are too soluble in water to persist for any distance

Autochthonous limestones Primary agents in the formation of autochthonous limestones are the *lime secreting organisms Most important of these* are the calcareous algae such as *Lithothamnion* and *Halimeda* two forms that make up the major part of reef limestones Foraminifera al o contrib ute large quantities of carbonate Other group of *carbonate rock forming invertebrates are mollusks* echinoderms (in particular the crinoids) and cor als Although many reefs are termed coral reefs *quantitatively the corals play a secondary role in* carbonate accumulation *See* ALGAE FOSSILS

The most common autochthonous limest one has been called *normal marine lime tone Although* whole fo sils or parts of them are plentiful the bulk of the rock may not be recognizal le a fo il *debris Much of the now unrecognizable material* prol ably came from calcareous algae or other l io genic carbonate that may have l een l roken up into *very small particles by the action of bottom dwell* ing scavengers Inorganic precipitation may ac count for ome of the fine grained calcite The rock *is light colored and normally has moderately well* developed bedding Dolomitization is common as are chert nodules

Some limestone formed by the accumulation of organic structures may be either autochthonous or allochthonou Among the varietie included in thi group are (1) biohermal lime tone (2) bio-stromal lime tones and (3) p lagic lime tone

(1) Biohermal limestones are reefs or reeflik mounds of carbonate that accumulated in much th ame fashion as the modern reefs and atolls of th Pacific Ocean The mounds may range from a fev feet up to several thousand feet in diameter and hundreds of feet thick Some of the best describe fos il reefs are those of the Silurian y tem in Il linois Indiana and Wisconsin The central core o the reef is fossiliferous dolomitized and ma si e It grades radially outward into sparsely fossilifer ous well bedded reef flank strata that commonly dip away from the core Farther away from the core the reef flank beds grade into fine grained well bedded relatively unfossiliferous normal car bonate inter reef sediment *See* BIOHERM

(2) Bio tromal limestones are biogenic carbon ate accumulations that are laterally uniform in thickness in contrast to the moundlike nature of bioherms The fossils may be of many different kinds or they may be dominated l y a single group Particularly common are crinoidal and algal bio-stromes The algal l iostromes may how very few recognizable fossils but stromatolites and algal laminations are common Many of the biostromes are of mixed autochthonous and allochthonous ori gin for some of the fos il del ris hows evidence of transport *See* BIOSTROME STROMATOLITE

(3) Pelagic limestones are formed from the ac cumulation of the limy parts of pelagic or floating organisms such as foraminifera The re ulting lime-stones are fine grained and contain very few fo il of l ottom dwelling faunas Since the foraminifera are chiefly responsil le for pelagic lime tone and the lime ecreting pelagic foraminifera did not evolve until the Cretaceous pelagic lime tones *are restricted to Cretaceous and later system See* FORAMINIFERA FOSSILS

Allochthonous limestones The allochthonou or tran ported lime tone show cla tic textures typi cal of detrital rocks The clastic particle may l e *of fossils as in coquina or coquinoid lime t ne* of inorganically precipitated carbonate particle as in oolite or f earlier dep ited lime tone

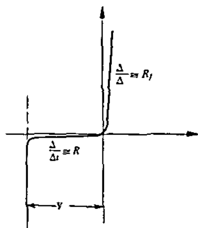
See CALCARENITE CHALK COQUINA MARL SEDIMENTARY ROCKS SEDIMENTATION (GEOLOGY) TRAVERTINE TUFA [R S]

Bibliography I Cayeux *Les Roches Sedimen taires de France Roches Carbonatees* 1935

Limiter circuit

An electronic circuit u ed to prevent tl e amplitude of an electrical waveform from exceeding a de sired le el while pre erving the hape of the wa e form at l wer than the specified level Such limiter may l e u ed to prevent the excur ion of a wave form from exceeding a pecified level in either tl e po itive or negative going direction or in f tl i multaneously

Limiting i usually accompli he l l y making u of the n nlin ar v oltage current relati n l ip in an electronic device A emic nduct r r va uum h l u ed a a clamp (s e CLA IPING CIRCUIT) i ften the key element in a limiter cir uit Tl e v ltag



Fg 1 V lt ge-curr t ch ct t f j ct diod

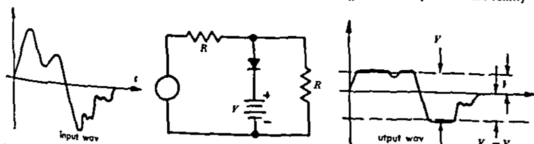
current cha teri t of typ al semi nd ct diode i h wn i Fig 1 I the fi t q dr t th haracterist i th t f the f rwa d b a ed d ode Here the har t t c m y be ppr imated by a E ar es tan e f l w v l Th al e m ght r g from few hms f om ju ti d odes t several h d ed hm fo a typ l ac m t be did I the th d qu d a t r er e b a reg the ch cte t may be appr imated by n tremel larg l ear res ta c u til the dd n b eak in the vi inity f I oc ur At th point, known the Ze br kd w oltag the c rre t becomes es ent ll i depe d nt of ltage (e SEMI O DUCTOR) E the the sh rp tr sit on that curs h g g f om th reve to-f rw rd bia condition or the Zen r egi n m y be sed f lim ting.

The se f both h t ri t cs s m lta eo ly s illustrated in F g 2. The p s ti e mpl t de of the tput wav f m is l mited app oximat ly at th r fer e oltage I a d the n g ti e mplit de i lim ted at a level I $-V_B$ c rr pondi g to th b e kdown ltage f mag tu le V_B Sharp l miting in the f rward l a d rect n i h eved wl n th f rward res tance R_f i m ll comp red t the re er bia re tance R wl en R_f i mall c m pared t R a d when any hunti g l ad resi tan e R_2 is la ge c mpared t R_f

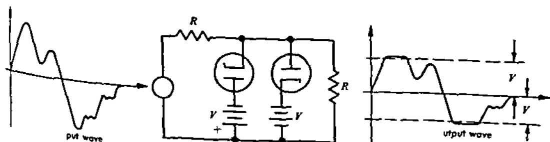
The vacuum d ode m y be ed a l m t r using the f rward re er e bias r g on I ut it has no usef l breakd wn imilar to the Ze r regi n of the ju tion diode If either po iti negati e limiting i req ired e ther uum r emic duc tor d ode may b u-ed with tl e r feren oltage a d th diode pol ity rever ed If bid r ct al limiting i des ed the c cuit f F g 3 may be ed with two d odes d tw sep rate l lt ages

M lti l ment electr n t bes or tr n i t rs al o may be u ed a l mite s G d-c r ent lim ting f a cuum tube i h wn F g 4 N rm lly wh n sed an mpl fier the g d neg ti w th r pect t the thode a d th input res t n e i h gh If the grid bec mes p ti e with respect t th cathode gr d c re t fl w a d th input re i t ce i l w In thi respect the g d-cathode ir cuit f the tub bel es a a um d ode w th th wa f rm lim ted s h wn The pl t circuit r t in it ampl ficat n p pe ties and the mpli fier plate- lt ge w ef m f the nl m ted por ti i i e ted h wn

Th at rat n ch r ter ti of th o tp t c r u t f a pe tode v c m tube or a mm -em t ter tra t m y also be d to bt n limit ng Th cu t of a h dev ce nd th o tput harac t r t c whi h may be ppl ed t e th device h wn in Fig 5 F r the pe tod the family f



Fg 2 Co b d se bia d Z b kd wn l mit g



Fg 3 Bid ctio l l m t g g tw d d

intergranular calcite If the particles are and size the rock is termed calcarenite In general the mechanically deposited limestones how the ame kinds of sedimentary tructures as do clastic rocks Cro s bedding stratification current lineation and even graded bedding may be displayed Oolitic and pi olitic textures are most abundant in limestones *See* OOLITE AND PISOLITE

Secondary textural features that are found in limestones include *stylolites (cro s cutting veinlets* filled with calcite) and replacement effects (typically that of rhombohedrons of dolomite replacing calcite) Because the carbonate minerals are relatively soluble in aqueous olutions and becau e of the transformation of aragonite to calcite and calcite to dolomite recrystallization and other diagenetic effects are particularly common in limestones *See* STYLOLITES

Classification Limestones are divided into two major groups the autochthonous and allochthonous The autochthonous limestones have been formed in place by organic or biogenic precipitation from the water of the environment usually sea water the allochthonous have been transported from the site of original precipitation the depositional agent primarily re ponsible being current action The total distance of transport of allochthonous particles may not be great the transportation is mainly a process of moving a chemical pre ipitate from one part of a sedimentary basin to another Carbonate minerals of sand or finer sizes are rarely found in surface streams and rivers for they are too soluble in water to persist for any distance

Autochthonous limestones Primary agents in the formation of autochthonous limestones are the lime secreting organisms Most important of these are the calcare us algae such as *Lithothamnion* and *Halimeda* two forms that make up the major part of reef limestones Foraminifera al o contribute large quantities of carbonate Other group of carbonate rock forming invertebrates are mollusks echinoderms (in particular the crinoids) and corals Although many reefs are termed coral reefs quantitatively the corals play a econdary role in carbonate accumulation *S e* ALGAE FOSSILS

The mo t common autochthonous lime tone has been called normal marine lime tone Although whole fos ils or parts of them are plentiful the bulk of the rock may not be recognizable a fo il debris Much of the now unrecognizable material probably came from calcareou algae or other biogenic carbonate that may have been br ken up into very small particles by the action of bottom dwelling scavengers Inorganic precipitation may account for ome of the fine grained calcite The rock is light colored and normally has moderately well de eloped bedding Dolomitization is common a are chert nodules

Some limestones formed by the accumulation of organic structures may be either autochthonou or all chthonous Among the varieties included in thi group are (1) biohermal lime tones (2) bio tromal lime tones and (3) pelagic limestone

(1) Biohermal limestone are reefs or reeflike mound of carbonate that accumulated in much the ame fa hion as the modern reefs and atolls of the Pacific Ocean The mounds may range from a few feet up to everal thou and feet in diameter and hundreds of feet thick Some of the be t des ribed fo sil reefs are those of the Silurian system in Illinois Indiana and Wi consin The central core of the reef is fossiliferous dolomitized and ma i e It grades radially outward into sparsely fo silifer ous well bedded reef flank strata that commonly dip away from the core Farther away from the core the reef flank beds grade into fine grained well bedded relatively unfossiliferous normal carbonate inter reef ediment *See* BIOHERM

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See CALCARENITE CHALK COQUINA MARL SEDIMENTARY ROCKS SEDIMENTATION (GEOLOGY) TRAVERTINE TUFA [F.J.P.]

Bibliography L Cayeux *Les Roches Sedimentaires de France Roches Carbonatees* 1935

Limiter circuit

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Limiting i u ually accompli hed by making u e of the nonlinear voltage current r lati n hip in an electronic de ice A miconduct r or vacuum di d u ed as a clamp *(se CLAMPING CIRCUIT)* i ft n the key element in a limiter circuit Th voltage

ndition for prod ct ty Lakes with poor phy i al co dit f the prod t n of organ ms a d ith l n trient le ls are k wn as lig trophic lakes. Lakes w th e cellent phy ical c ditions f r the producti n of orga i m and w th high nutrie t evels are kn wn eutrophic lakes Lakes tend t ecome m re prod ct e thro gh the acti ties f ber g nı.ms, ps ing from oligotrophic t eu m hi types.

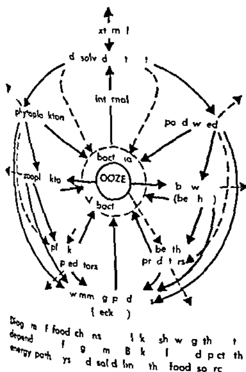
Factors influencing productivity The primary act rs eces ry f the prod ctio of aquatic or anism are nl ght and certain inorganic and or anic substances d sol ed i th water or co ained in the a soc ted bottom material These bstan es in l d the d ol ed ga e m t im ortant of h ch ar oxyg n a d carbon d xide nd ino d sol ed sol ds such a compo nds of nitrogen, phosphorus and other elem nts all f hich ha e interrel ted hem cal r cti n The seco dary facto f body of water controll ng the velocity and lim ting the prod cti n of aquatic life re th shape area, ari us d mensions bott m types, temper tures, c rrents, t bid ty amo nt nd d pth f l ght penetr t n a d ther phy cal conditions.

Food cycles The aqu tic rg n ms devel p fro the sam h m l n tr e ts tho e that up- port terrestrial rg ms Th b ic o ga i ms re h plants h h u the r w nut ient ub ta ces and support th animals by c mplicated food chains. Definite cy les are mai ta ned between the organism and th nutrients the hemi al elem ts b g con erted into li i g org ni ms wh ch d and decompose b k into the ga c a d in rg n c u trients The whole p oces is b ed o the ph to- ynthetı cti ty f all aquatic pl nt utilizi g solar energy received l y rad ti n and is c ntr lled by the v rious physical fa t r Th tran fer l energy can be traced thro gh the ariou levels of the food chain

Gen al habit ts f organ ms The aq atic or ganisms are gr uped int var us categ ries ac rd ing to where they li e The mo t o t ta ding group are the micr c pic plants and animal l ing sus- pended in the open water the pla kton the organ i m li g in or the bott m the benth o the larger fr e sw mm g nim l the ekt n and the rooted plants or p nd weed l ing i the h ll w water

Zo ati n in aq atic hab tats Standing wat r re d vided i to zones a c rd ng t the condit n for l fe The littoral z ne i the h ll w area lim ted by the depth of s ff nt l ght pe etr tion f r g wth of rooted pl nts Th l mnet c zone i the pe wa te beyo d the l ttoral zone and i i hab ted by pla kt n a d e me n kto The pr f nd l zone ex i ts bel w the l mnetic zone in waters deep enough to develop temper ture strat f cati wh ch f r part f the y ar restrict the l we waters from c r u lating w th the ppe wat Runni g waters are di ided mainly int z nes cr ated by ondit n of curre t and by rel ted bott m types w ft water (rap ds) z nes a d lugg h w ter (pool) z es ea h with ch ra ter tic orga ms. *Se* ECOLOGY FRESH WATER ECOSYSTEM LAKE MARINE ECOSYS- TEM OCEANOGRAPHY PHOTOSYNTHESIS [S E]

Bibliog aphy G E H tch nson *A T eatise n L m ol gy* l 1 1957 R L. Li dema Se sonal food-cycl dynamic i a enesc nt lake *Am Mid land Natu alist* 26(3) 636–673 1941 F R tt er *Fund mentals of Limn logy* 1953 P S Wel h *Lim ology* 2d ed 1952.



Diag m f food ch ns l k sh w g th t depend f g m B k l d p ct th energy path ys d sol d lin th food so rc

Limonite

A n tu l amorph s- pp a ng material c n ti t t ng n part the materi l kn wn a br wn ir n e Lim ite occu s n m mmillary stala titic, nd e rthy mas es The ha d es i 5–5 5 (Mohs scale) a d the pe ific gravity is 3 6–4 The l t r itreo s nd the l r da k brown t bla k Lim n te s essent ally FeO(OH) nH O b t w th dmixed h mat te lay a d ma g es des X y n lys s h h wn that m h f the mat i l f rmerly th ught to be l m nite s goeth t L mo it f rm by the o d ti n of p e x t g r mi e al d occu s with goeth t It i th pig me ti g m t al in y llow ls and mixed w th fi e lays k wn y llow che *S* GOETHITE IRON (EXTRACTION FROM ORE) ORE AND MINERAL DEPOSITS [C.S HU]

Limpet

Any f ever l pecies f the Class Ga tropoda phyl m M llu a h r cteri ed b a nical t t lik h ll Two famil es a g ner lly re gn ed the A m d w thout an pe i g at th apex f th h ll d the Fi s r llidae which ha ith r a small pe ng at th ap of th shell or ne

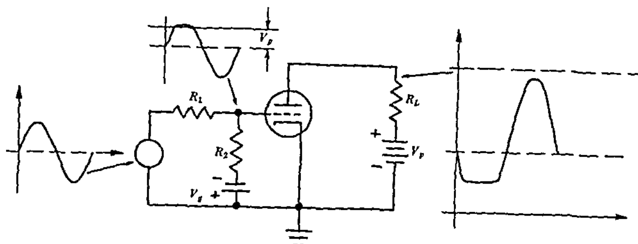


Fig 4 Grid-current limiting

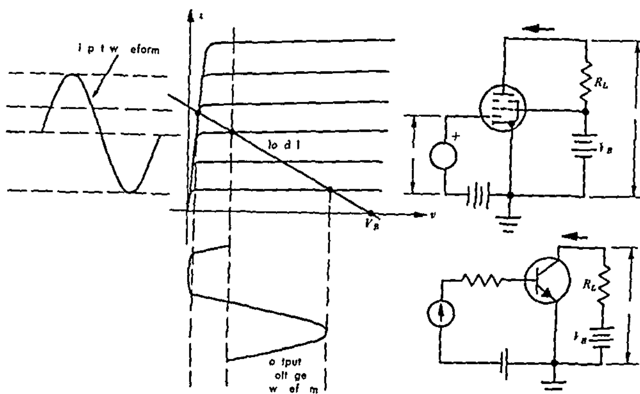


Fig 5 Output circuit saturation limiting

curves represents plate current as a *function of* plate voltage for various values of grid voltage for the transistor they are collector current as a function of collector voltage for values of ba e cur*rent (see* PENTODE VACUUM TRANSISTOR CONNECTION) Either *n p n* or *p n p* tran i tors may be u ed according to the de ired polarity of the out put waveform The graphical con truction shows *the input output transfer* characteri tic a deter mined by the input ignal swing and the value of the load resi tance R_L The output is limited by the saturation characteri tic

The term *limiter* is often defined in sufficiently broad terms to include th related operation of clipping (*see* CLIPPING CIRCUIT) which al o re ults in the deletion of a portion of a waveform Limiters and clippers are often u ed t gether par*ticularly where* both negative and po iti e peaks of *a resultant waveform are to be rem ved rather* than bidirectional limiter u ed alone

For other wave haping circuits *see* WAVE SHAPING CIRCUITS [G M C]

Limnology

The science of the life and conditions for life in lakes pond and stream It involves the study of the physical and chemi al conditi n of bodies of water and the produ tion of all organi m sul ject to the e conditions The ultimate re ult of the e studies is the determinati n of the productivity in terms of the am unts and kind of aquatic organ i m Limnological studies are of imp rtanc to any activity in olving the u e of bodies of fre h wat r such a the management of fi l erie water upplies p llution sewage re ers ir and impoundment Bodie of water are cla ified according t th ir

d ns f prod ti ity Lakes with poo phy i al co d t s for the product n of ga i m and with l tr e t levels are kn wn as l g trophic lakes. Lakes w th excelle t phys c l co dition for th prod ction f o g i m and w th high nutrient levels are known as eutrophic lakes Lakes te d t become m e p od ct e through the a ti t es of t i r gani m ps. i g from ligotrophic to eu trophi types.

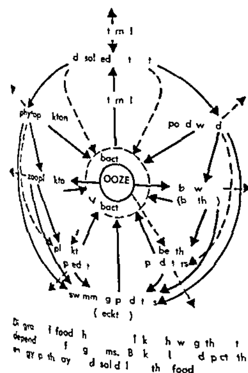
Factors influencing productivity The primary facto neces ry for th p oducti of aquatic or gan rs are s nl ght a d certa n inorgani and or ganic sub tances d ssol ed i the water r c n tained m the oc ted bott m material These substa ces incl d the d ol d ga es m t im portant of wh ch are ox gen and carbon d oxide and ario d sol ed solids uch as compounds f trogen, ph ph ru and other elements all of hich h e interrel ted chem cal reacti s The seco dary factors of a body of water controlling the loc tr a d lim ti g the p od ctio of aquatic l fe th hape a ea, a o s d men ns bottom types, temper tures c rr ts t rbidity am unt and depth f light penetr tio a d other phy ical nditi

Food cycles The aqu tic rg ni m d elop from th sam h mi al n trients as tho e that up port t rrestri l rga i m The basic org ni ms are th plants whi h u e th r w n t ie t s b ta ces and support th nimal by c mplicated food chains. Definite y les a e m nt i ed between the organ ms a d th utrients th chem cal eleme t be g co erted int l ng o g ni ms wh ch d e a d decompose back into the rga c nd i g ic u trients. Th wh le p ocess is b ed o the ph to-sy thetic acti ty of all aqu tic pla ts utilizing solar energy recei ed l y radi ti n and i c ntr lled by the vari us phy cal fa t rs The transfer f energy can be traced through the ari u levels of the food chai

G ner l hab t ts of org isms The aquatic r gani ms are gr uped i to ario categ ries acc rd ing to where they li e The m t outstand g gr ps are the micro pic pl nts and animal li ing is-pended in the open water the plankt the rgan i m l i g i r o the bott m th b ntl the larger fr e wimmi g an m l the nekt n and the rooted pl nts or pond weeds l i g i the hall w wate

Zo tion i aquatic habit ts Standing w ter are di ided into zones a c rd g t tl e cond ti n for life The littoral zon is th hall w are l mited by the depth of s fficient light penetr ti n f r gr wth of rooted plants The l m etic ne the pen wa ter bey nd the l ti ral zone d i inhabited l y plankt n and some nekton The prof dal z n ex ists below the l mnet zone in waters deep n gh t devel p temper ture tratif c ti whi h f r part of the y ar restrict the l wer wate s fr m cu lat g with th upper wate R nni g w ters are di ided mai ly i t zo es cr ted by d t on of current nd by rel ted bottom types wift w ter (rapid) z es and l ggi h water (pool) z nes each with characteri tic rgan m *S e* ECOLOGY FRESH WATER ECOSYSTEM LAKE MARINE ECOSYSTEM OCEANOGRAPHY PHOTOSYNTHESIS [S E.]

Bibl gr phy G E Hutchin n *A T eatise n Lim ology* v l l 1957 R L Lindem n Season l food-cycle dynam cs a es nt l ke *Am M d l d Nat list* 26(3) 636–673 1941 F Ruttn r *F d m tal of L mn logy* 1953 P S Welch *Limnol gy* 2d ed 1952.



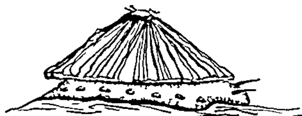
Di gra f food h depend f g ms. B k l d p ct th en gy p th oy d sol d l th food

Limonite

A n tur l morphous- ppear g materi l ti t ting n p rt the m teri l known s brown ir n re Lim te occ s i m mmill ry st l titi nd rthy m sses The h rd ess is 5–5.5 (Mohs cal) a d the specifi gr ity is 3.6–4 The l t r is t eo s d the col d rk br wn t black Lim te s se ti lly F O(OH) nH O b t with dm ed hemat te lay a d ma ga ese des X y a aly s h s sh w th t m ch of the material forme ly th ght t b limon t is goeth te Li m it f rm by the o d tio f p e i ti g r n mi als a d o ur w th goethite It s th pig me t ng m t r l y ll w l a d m ed w th fin lay i k own y ll w ch S GOETHITE IRON (EXTRACTION FROM ORE) ORE A D MI ERAL DEPOSITS [C.S HU]

Limpet

Any f se al sp ies of the Cl s Gast opoda phyl m M ll c h ra t i ed by a c c l te t lik sh ll Tw f mil es e g n ally re ogn zed the Acm e d e w tho t n p g t the apex of th h ll and th F s llid whi h has th r m ll p g at th pe f the bell o o



The limpet Patella sp length to 2 in

marked by a slit or notch along the margin The surface of the shell in the latter family is usually strongly ribbed

Limpets are utilized for food to a limited extent in Europe and to a much lesser degree in the United States They are also utilized as fish bait and their shells are frequently used as ornaments

Most limpets are small animals 2 in or less in length Except for shell and foot shape they are essentially like other snails in their anatomy (see SNAIL)

Their choice of food is varied as many limpets are highly specific in their diet Some scrape algae from rocks others eat organic detritus some feed on a single species of seaweed and at least one eats only eel grass

Most limpets have separate sexes and discharge their sperm and eggs into the sea Some species are known to be functional as males when young but change into females when 2 or 3 years old Limpets live a surprisingly long time for small invertebrate animals There is one record of a Japanese species known to live for 17 years others live at least 10–15 years

Limpets have a strong homing instinct spending virtually their entire life at a precise place on a rock leaving the spot only to feed The shape of the shell of many limpets conforms to the contour of the spot where they live

The white cap limpet is a common Pacific Coast form about 1 in long The shell has a smooth white surface but it does not have an opening at the apex The rough keyhole limpet also a common Pacific Coast form is characteristic of the family Fissurellidae with an opening at the apex of the cone and the shell marked with strong ridges Its color varies from dark purple to gray brown The keyhole limpet of the Atlantic Coast is a similar warm water species ranging from Florida southward It is white to buff in color Several other species occur along both coasts See GASTROPODA

[J D R]

Line

In axiomatic geometry a line frequently is taken as a primitive (undefined) concept an element in line geometry a class of points in a geometry with point as element whose essential properties are stated as axioms In analytic geometry a line is identified with (or is the graph of) a linear equation $Ax + By + C = 0$ with A $B \neq 0$ 0 in cartesian coordinates $(x\, y)$ As a derived concept line is defined in terms of primitive notions such as distance or betweenness For example a line L is a set of points in one to one correspondence with the set of real numbers such that if points p q of L correspond to numbers x y respectively then distance $(pq) = |x - y|$ or if p q are points the line $L(pq)$ is the set of points consisting of p q and all points x such that one of the points p q x is between the other two See ANALYTIC GEOMETRY GEOMETRY EUCLIDEAN PLANE POINT

[L M BL]

Line integral

The line integral of a vector function **F** of position over a path C is

$$\int_C \mathbf{F} \cdot d\mathbf{r} = \int_C F_x(x\, y\, z)\, dx + \int_C F_y(x\, y\, z)\, dy + \int_C F_z(x\, y\, z)\, dz$$

where F_x F_y F_z are the scalar components of **F** along the coordinate axes The path C is supposed to be a curve smooth at least in part defined parametrically by equations of the form

$$x = x(p) \qquad y = y(p) \qquad z = z(p)$$

for each smooth portion The function $F_x(x\, y\, z)$ etc must be defined at all points of C When this is so the line integral can be evaluated by writing

$$\int_C \mathbf{F} \cdot d\mathbf{r} = \int_{p_1}^{p_2} F_x(p)x'(p)\, dp + \int_{p_1}^{p_2} F_y(p)y'(p)\, dp + \int_{p_1}^{p_2} F_z(p)z'(p)\, dp$$

where the prime means differentiation with respect to the parameter and p_1 p_2 are values of the parameter at the end points of the path C or of a smooth piece The integral has been converted into an ordinary definite integral

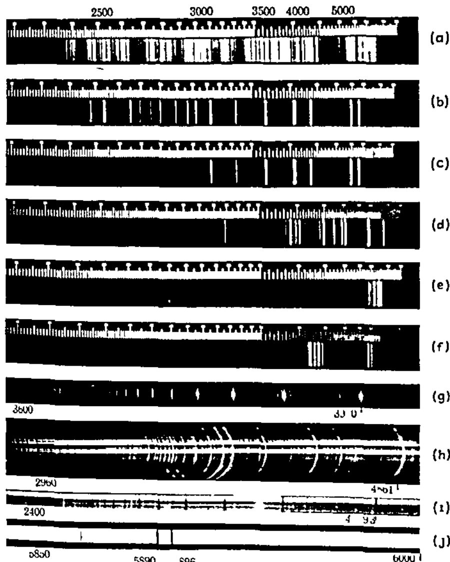
When C is a closed curve the line integral is called a circuit integral and is written

$$\oint \mathbf{F} \cdot d\mathbf{r}$$

Some physical applications of the line integral follow If **F** is a force the line integral is the work done in moving a mass along the curve C If **F** is the velocity of flow of a fluid the line integral is the circulation of the fluid along the curve If **F** is the electrostatic field strength the integral is the electric potential difference between the end points of the curve If **F** is the electric field strength of an electromagnetic field the circuit integral is the electromotive force of the circuit In each example $d\mathbf{r}$ is physically a length See INTEGRATION [M H H]

Line spectrum

A discontinuous spectrum characteristic of excited atoms ions or molecules in the gaseous phase at low pressure If an electric arc or spark between metallic electrodes is viewed through a spectroscope the light source is seen in all colors characteristic of the metal atoms or ions In order to avoid overlapping of the spectral images the



Ph tog ph f mm l p ct w l gth g g t m m p t ( ) t (f) ll t k th th sam q rtz p ct g ph ( ) Sp t m f iro (b) M ry p ct m f m l d in q rtz. ( ) S m f m l d gl (d) Hel m a gl d h g t b ( ) N i gl d ch g tub (f) A g gl d h g t b (g) Balm f hydrog th lt l t grat g p ct m (h) Em p ct m f m g ch m ph f th S g t g pect m t k h t lt t th t t mm d t ly p d g tot l l p wh th t f th S d by th M d k Tw t g st m g H d K l f l m h w m k d p ml cl d f l m p Oth t g l d by hy d g d h l m ( ) L b pt o p ct m f d m th lt l t t k w th g t g B ght l b kg d o th h b l ght t b rpt b y d th e l m t (j) S l p ct m i th ghb h od f od m D l s. Th D l (5890 A d 5896 A) b- b d by d m p th h m ph d to- g th t t t th fi t m mb f th h w () (F m F A J k d H E Wh t F d m t l f Opt 3d d McG w H ll 1957)

pect osc p p ded w th ry narr w l t wh h ıll m ted by th l ght o c a d th pectrum th n rr y of b ght l m g of th l t d k b kgr d Li p t a d ot cc t lly b t lt f m s f rt fi l l l ght e—th l t—bec t g es th l t c f f l pp g m g S ATOMIC STRUCTU A D CT SP CT O CO Y [W F M]

Linear accelerator

A part le eler t r wh h a lerat el t n p t n h a y s ın tra ght l e by th c t n f alt rnat g lt ge It h b en uc e sful ele atı g l tr n t el c tie ry ea that f l ght F a e t ded d us e PAR TICLE ACCELERATOR [W K H P]

Linear energy transfer (biology)

A physical factor which is significant in biology because in many biological actions of high energy radiations linear energy transfer (LET) strongly and characteristically modifies the quantitative re lations between dose and effect *See* RADIATION BIOLOGY

When a moving charged particle (for example an electron or proton) traverses matter it progres sively loses kinetic energy which is gained in di verse amounts by individual molecules along its path The amount of energy thus transferred per unit length of path is the LET It is roughly pro portional at least in gases to ionization per unit path (specific ionization ion density) LET in creases as the particle s velocity decreases accord ingly it varies greatly along any individual path and is maximal near the end Also LET increases as the quare of the charge on the particle for ex ample the LET of an α particle is four times that of an electron or proton of the same instantaneous velocity

For experimental purposes different values of LET can be obtained in two general ways In the track segment method a beam is used made up of particles (protons) that have uniform initial veloc ity and produce substantially traight tracks The experiment is so arranged that they all traverse a sample of biological objects with the same linear segment of their paths Different LET values are obtained by using suitably different path segments In the track average method either entire paths are spent within the biological object or random linear segments of different paths traverse it Dif ferent average values of LET are obtained by us ing radiations that produce suitably different spec tra of LET Although the average usually used is the arithmetic mean other averages will probably be found to be more meaningful as greater under standing of radiobiological mechanisms is achieved

In some radiobiological actions the shape of the do e effect curve is changed as LET is varied How ever these cases are rare in comparison with tho e in which only the slope is changed In the latter case the effect of LET can be expres ed by a single parameter (radiobiological effectiveness RBE) which varies as the slope (or a the reciprocal of the dose in rads required to produce a given de gree of effect)

For ome radiobiological actions RBE decreases with in rease in LET this is exemplified by in activation of macromolecules viruses and certain bacteria For other actions RBE increases with LET in some of these ca es RBE has been shown to pass through a maximum there are theoretical reasons to believe that maxima would be observed for all of them if larger values of LET were experi mentally available *See* RADIATION MICROBIOLOGY

The distribution of individual energy transfers along a path corre ponds to the di tribution of ion ized and excited molecules production of which is believed to initiate the radiobiological mechanism Because of diffusion this distribution in space lasts only 1 μsec or less Thus the observed varia tion of RBE with LET demonstrates that ome es sential part of the radiobiological mechani m is completed in a very short time

Among other interesting facts are the following (1) In at least some radiobiological actions the influence of LET is modified by other factors uch as concentration of molecular oxygen (2) Influ ence of LET is also encountered in radiation chem istry For instance the decomposition of liquid wa ter depends strongly on LET and this dependence is modified by oxygen Facts such as these make LET of prime interest in attempts to under tand radiobiological mechanisms *See* RADIATION RADI ATION BIOCHEMISTRY RADIATION INJURY (BIOL OGY) [R E Z]

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Linear programming

A branch of mathematics centered about the find ing of the point on a convex polyhedron where a linear function achieves a maximum or minimum Although such questions have existed in mathe matics for over a century a systematic approach has existed only since World War II

The principal interest in linear programming is that many business problems can be conveniently described by it (*see* OPERATIONS RESEARCH) Lin ear programming is also applicable to problems in physical science economics and other parts of mathematics

General theory A typical linear programming problem is to

$$\text{maximize } c_1x_1 + \quad + c\ x$$

where x_1 $\quad x$ satisfy the conditions

$$x_j \geqq 0$$

$$a_{11}x_1 + \quad + a_1\ x \leqq b_1$$

$$a_{m1}x_1 + \quad + a_m\ x \leqq b_m$$

The a_{ij} c_j and b_i are constants x_1 $\quad x$ are variables

Sometimes the problem may be to minimize rather than to maximize sometimes some of the variables may not be re uired to be nonn gati e som times some of the inequalities $a\ x_1 + \quad + a\ x \leqq b_i$ may be reversed or be equalitie

The linear inequalities which the variables sat isfy correspond algebraically to the fact that the variable point $x = (x \quad x\ )$ lies in a c nvex polyhedron Hence the principal mathematical bases for linear programming are the theory of lin ear equalities a part of algebra and the theory of convex polyhedra a part of geometry Th m t im portant theoretical f undati ns are a foll ws

If the function $c_1x_1 + \quad + c\ x$ d es n t g t arbitrarily large for points $x = (x_1 \quad x\ )$ on the con ex polyhedron then a maximum i attained at a vertex of the polyhedron

If there is a maximum i the stated probl m then there is a minimum in the dual problem of minimizing $b_1y_1 + \quad + b_my_m$ where $y_i \geqq 0$

$$a_{11}y_1 + \quad + a_{m1}y_m \geqq c_1$$

$$a_{1n}y_1 + \quad + a_{mn}y_m \geqq c$$

Further the m xim m and minimum are the same numbe This d ality theorem is es ent ally equi a lent to the minim the rem (see GA IE THEORY) Both th duality theorem and the min max theorem are alg b ai p raph es l the geometric fact that if a point s n t ntai ed i a con ex polyhedr n then a hyp rplane can be f und which eparate the point from the polyhedron The duality theorem also cl sely related t the c n ept f Lagrange multip rs (s e CALCULUS OF VARIATIONS)

Methods of calculation The m t popular ethod f r solvi g l near programs th t is, the finding of the = (x ,x) which maximizes c + $+ c_nx$ is the s mplex method de el ped by Geo g B Dantzig in 1947 The method is geometri ally a proce f m ing fr m ertex to neighboring rt x o the con ex polyhedron e ch move a ng higher lue f c x + + x_n until the rtex yi ld ng the greate t lue i rea hed. Algeb ally th calcul tio s re s milar to e minat n p ocesses for ol g systems f al geb ic equ ti These alculat s re g e ally perf rmed on n electr i c mp ter u le s the number f ari bles nd c t a nts i mall

There ha e also be n dev l ped pec l method f calcul ti t l m d fo part cular l ses of li ear p ogramm ng p bl m uch as the tra p r tation p blem d sc sed below

Applications Let a_{ij} denote the numbe of un t of nutrient j p esent in o e un t of food Let j be the mi im m amou t of nutrie t j eeded fo satisfactory health, b be the u t price of food i Let the v riables y d n te respecti ly the number f units f food i t be bought The the d al problem is th so-called d t p blem t ma nta n ade qu te n triti n at least o t It h been u ed in planni g f ed g p og m f eral a et e f livestock and poultry W th d ffe t i terpreta tion of th symbol th am form t descr bes th p blem of mbin ng aw materi l in a h mi al proces t p od c qui ed nd p du ts as cheaply po s ble

In an the it i n l t ; be th t of hip ping a u t of g e p od ct f m w rehou e i to cu t m j f all m w h uses i and ll n cust m s, p rtain ng to a bu ess Let be the m t l l e t wareho e d b_j the mount requ ed by tom r j The tr n-p rt t on pr bl m is to h p th requ ed mounts to the cu tom at lea t cost. Thus, if x_{ij} is the am unt t b h pp d fr m to j then minimize

$$c\ x\ + \qquad + c_m\ x_m$$

here $x_{i1} + \quad + x \leqq a_i \quad i = 1 \quad m$
and $x_{1j} + \quad + \ _{mj} = b_j \quad j = 1 \quad n$

The f reg ing are r presentati e of the bu ine appl cations of linear pr gramming everal hun dred of whi h ha e n w been reported Th e be t known appl cati o t ide bu ine have l een to eco om c theory and t e ml natori al analysi In both in tance the duality th rem has been u ed to illumi ate and gener lize p evi u result

In quadratic programming th e object is the mi imization (maximizati n) of a po it ve emid finit (negative semidefi ite) qu dratic form o er a con vex p lyhedron (see MATRIX THEORY) Eff cient calculation pr cedures l uilding on the implex method are kn wn for th quadratic a e In n n linear pr gramming the functi n to l e minim z d or max mized is e en more ge eral the restraints m y al o be nonli ar and eff cient procedures a e known only for pecial ca e [A J H]

Bibliog phy S I Cas *L near P ogr mm g* 1958

Linear systems of equations

Sy tems of m thematical equations f th form

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \quad + a_{1n}x &= b_1 \\ a_{21}x_1 + a_{22}x_2 + \quad + a_{2n}x &= b \\ a_{m1} \quad + a_{m2}x_2 + \quad + a_{mn}x &= b_m \end{aligned} \tag{1}$$

wh re the a_{ij} = 1 2 m j = 1 2 n and the b i = 1 2 m are con tant or fixed numbers and the x i = 1 2 n a e called unkn wns System (1) i r fe red to as m l ear equati ns in n unk own A olution of system (1) is a et of n mbe s c c c a ch th t when x s epla ed by c x_2 by c_2 x by c e ery quat o of y t m (1) b c mes a true equality The problem po ed by such a s tem of equations is to find criteria f r the exi ten e of a oluti n a d when oluti n e i t, to obtain system t e meth ds f find ng the solut on

An x mple f uch a linear sy tem of equa ti n i

$$\begin{aligned} 2x - \quad _2 \quad - x + 2x_5 &= 2 \\ x + 3x_2 + 4x - 3x - x_5 &= 4 \\ 3x + 2x_2 + 4x_3 + 2x + 3x &= 2 \end{aligned} \tag{2}$$

Th s system (2) ha infi tely m ny solut ns which ca be g ve the f rm $x = -c - \frac{1}{7}c + \frac{6}{7}$ $x_2 = \frac{1}{3}\ s - \frac{8}{7}c + \frac{5}{7}$ $x = c$ $x = -\frac{1}{4}c - \frac{2}{3}$ $x_5 = c$ h re c a d c_5 re a b trarily cho n numl er

Tw l ear ystems f equatio s ar equi alent i v ry sol t on of n of th sy t ms i ol ti n f th the and ce e a The sy tem (1) repl ed by n equ alent sy tem for wh ch the sol tion if th y ex t, re s ly fou d b per f rm ng ert n el m nt ry p r t o s on the equa t n These oper t o nte hang ng two equa tio addi g t e equat o an th equ ti m ltipl d by n tant, o mult ply ng an eq ti n by a n zero on t t By equ n e of uch pe at ns, y tem (1) c b repl c d by a equ l nt system of the foll wing form

$$\begin{aligned} x_{1} + d_{1\ i+1}x_{i+1} + d_{1\ \ +2}x_{\ +2} + \\ + d_1\ x = e_1 \\ x_{n_2} + d_{2\ s+1}x_{s+1} + \quad + d_2\ x = e_2 \\ x\ + d\ \ _{+1}x_{r+1} + \quad + d\ _n x = e \\ 0 = e_{+1} \\ 0 = e_m \end{aligned} \quad (3)$$

If $e_{1} = e_{2} = \quad = e_m = 0$ then the olutions of the system can be obtained by choo ing arbi trary values for the unknowns other than

$$x_{1} \quad x \quad\quad x$$

and solving the equations in turn beginning with the last equation for

$$x \quad x \quad\quad x_{2} \quad x$$

When the system has solutions it is said to be con sistent If any one of $e_{1}\ e_{2} \quad e_m$ is not zero then the equations do not have a solution and are inconsistent In the example (2) the system is equivalent to the system

$$\begin{aligned} x_1 + 3x_2 + 4x_3 - 3x_4 - x_5 &= 4 \\ x_2 + {}^8\!/_7 x_3 - {}^5\!/_7 x_4 - {}^4\!/_7 x_5 &= {}^6\!/_7 \\ x_4 + {}^1\!/_3 x_5 &= -{}^2\!/_3 \end{aligned}$$

Arbitrary values c_5 and c_3 can be chosen for x_5 and x_3 respectively and the equations can be solved successively for $x \quad x$ and x_1

The operations used in reducing system (1) to system (3) can be most effectively performed on the rows of the matrix of the system

$$A = \begin{pmatrix} a_{11} & a_{12} & & a_1 & b_1 \\ a_{21} & a_{22} & & a_2 & b_2 \\ \\ a_{m1} & a_{m2} & & a_m & b_m \end{pmatrix} \quad (4)$$

and they are preci ely the elementary row trans formations of a matrix (*see* MATRIX THEORY) The matrix (4) is called augmented matrix of the system and the matrix

$$A = \begin{pmatrix} a_{11} & a_{12} & & a_1 \\ a_{21} & a_{22} & & a_2 \\ \\ a_{m1} & a_{m2} & & a_m \end{pmatrix} \quad (5)$$

is called the matrix of the coefficients The rank of a rectangular matrix is defined and the method for *determining the rank i gi en in the article* on matrix theory A nece ary and sufficient condi tion for the existence of a olution of sy tem (1) is that the rank of the augmented matrix l he the ame as the rank of the matrix of coeff cients A In the example (2) the rank of the augmented matrix

$$A = \begin{pmatrix} 2 & -1 & 0 & -1 & 2 & 2 \\ 1 & 3 & 1 & -3 & -1 & 1 \\ 3 & 2 & 1 & 2 & 3 & 2 \end{pmatrix}$$

as well as the rank of

$$A = \begin{pmatrix} 2 & -1 & 0 & -1 & 2 \\ 1 & 3 & 1 & -3 & -1 \\ 3 & 2 & 4 & 2 & 3 \end{pmatrix}$$

is equal to 3 Therefore the system i con i tent and has the olutions given earlier

If $m = n$ in system (1) and if the determinant $|A|$ (*see* DETERMINANT) of the matrix of the co efficients A is not zero then the sy tem (1) has a unique solution which can be obtained by Cramer s rule which gives the values of the unknown x_1 $x_2 \quad x$ as the ratio of two determinant Specifically Cramer s rule gives

$$x_1 = \begin{vmatrix} b_1 & a_{12} & & a_1 \\ b_2 & a_{22} & & a_2 \\ \\ b & a_{\ 2} & & a \end{vmatrix} \bigg/ |A|$$

$$x_2 = \begin{vmatrix} a_{11} & b_1 & a_{13} & & a_1 \\ a_{21} & b_2 & a_{23} & & a_2 \\ \\ a_{\ 1} & b & a_{\ 3} & & a \end{vmatrix} \bigg/ |A|$$

$$x = \begin{vmatrix} a_{11} & & a_{1\ -1} & b_1 \\ a_{21} & & a_{2\ -1} & b_2 \\ \\ a_{\ 1} & & a_{\ -1} & b \end{vmatrix} \bigg/ |A|$$

In every case the determinant in the denominator is $|A|$ and for the value of the unknown x_i the determinant in the numerator is the determinant of the matrix obtained from A by replacing the ith column of A by $b_1 \ b \quad b$ If $|A| = 0$ in this ca e of n equations in n unknown the sy tem may either be inconsistent or it may have infinitely many solution In the example

$$\begin{aligned} x_1 - 4x_2 + 5x_3 &= 6 \\ 2x_1 - 11x_2 + 10x_3 &= -1 \\ 4x_1 - x_2 + 5x_3 &= 0 \end{aligned}$$

$$|A| = \begin{vmatrix} 1 & -4 & 5 \\ 2 & -11 & 10 \\ 4 & -1 & 5 \end{vmatrix} = 45$$

and the unique solution is given by

$$x_1 = \begin{vmatrix} 6 & -4 & 5 \\ -1 & -11 & 10 \\ 0 & -1 & 5 \end{vmatrix} \bigg/ 45 = -{}^{285}\!/_{45} = -{}^{19}\!/_3$$

$$x_2 = \begin{vmatrix} 1 & 6 & 5 \\ 2 & -1 & 10 \\ 4 & 0 & 5 \end{vmatrix} \bigg/ 45 = {}^{195}\!/_{45} = {}^{13}\!/_3$$

$$x_3 = \begin{vmatrix} 1 & -4 & 6 \\ 2 & -11 & -1 \\ 4 & -1 & 0 \end{vmatrix} \bigg/ 45 = {}^{267}\!/_{45} = {}^{89}\!/_{15}$$

If in system (1) $b_1 = b_2 = \quad = b_m = 0$ the syst m

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \quad + a_{1n}x &= 0 \\ a_{21}x_1 + a_{22}x_2 + \quad + \ _{2n}x &= 0 \\ \\ a_{m1}x_1 + a_{m2}x_2 + \quad + a_{mn}x &= 0 \end{aligned} \quad (6)$$

is called h m g neou S c the augmented matri f (6) differs fr m the matrix f the c efficient l y an dditi l column of zer the e matrices al ays ha e the ame r k so that a h m geneous sy em t l ys con i te t It h s the ob ious sol tion 0 $_2 = 0$ $x = 0$ which is called th t al sol t Any sol t with at leat e $x_i \neq 0$ s called no tr al A hom ge e u system of m equ t n in n kn wns ha n trivial sol tio if and ly if the ra k of th m trix f coeffi ts A i less tha n In particular f m l than n the ra k of A is at mo t m and the stem has a ont al solution Furth if $m = n$ the tem has ont i ial soluti if and only if th det rm t $|A| = 0$ In the y tem

$$
\begin{aligned}
3 \quad + 4 \quad - \quad x_3 &= 0 \\
-2x + 3 \quad _2 - \quad 4x_3 &= 0 \\
5 \quad + \quad _2 + \quad 2x_3 &= 0 \\
-9 \quad + 5 \quad _2 - 10x_3 &= 0
\end{aligned}
$$

the rank of

$$
A = \begin{pmatrix} 3 & 4 & - \\ -2 & 3 & -4 \\ 5 & 1 & 2 \\ -9 & 5 & -10 \end{pmatrix} \qquad (7)
$$

is 2, so th t the y t m (7) h s no tri l l tio Th r k f A is een t be 2 by perf rmi g elementary ro tr f rmat A to ed it to th form

$$
\begin{pmatrix} 1 & 4/3 & -\frac{1}{3} \\ 0 & 1 & -16/17 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}
$$

System (6) i equ le t t the sy t m

$$
\begin{aligned}
_1 + \tfrac{4}{3} \quad - \quad \tfrac{1}{3} x_3 &= 0 \\
x_2 - \tfrac{16}{17} x &= 0
\end{aligned}
$$

The soluti ns are g e by $x = -10/17$ $x =$ 16 7 c wher c_3 a rb t r ly ho e number

In the e ent that a l sy t m (1) h s nfi nitely many sol ti they c n be gi e a w the m the exampl (2) o lternati ly a finit numb f sol tio b l ted term f th h all sol ti n b en e tly bta d A fix d soluti f (1) i alled p rt l l tion. In th e mple (2) $x = \frac{9}{7}$ $x = \frac{8}{7}$ 1 0 $x = -\frac{2}{7}$, $x = 0$ p rticul sol ti If the sy tem (1) o s st t, ev ry lut on i f th f rm x_1 +) whe e + c = + c particular sol ti n f (1) d c s a fixed is any sol ti f the c rre pond g h m ge- neo system (6) By irtu of th s es It it i suffi t to in est g te th sol t s f th ho- mogeneo y tem (6)

Let C = ( ) c) d $C^{(}$ = c)) be s l t n f the ho- mogeneo y t m (6) wr tten a n t ples Then C + C (+)) + c) c_1 +) th m f the l t d eC ( ) whe e i a fixed number i a scalar multiple f th e soluti n $C^{( )}$ It is evident that any li ear combination $e\,C^{( )} + e\,C^{( )} + \quad + e\,C^{( )}$ of sol t n $C^{( )}$ $C^{( )}$ $C^{( )}$ of (6) i again a sol t on f (6) A set of l tio $C^{( )}$ $C^{( )}$ $C^{( )}$ f the ho- m g neous y tem (6) i called l nearly inde- pende t et if $e\,C^{(} + {}_2C^{( )} + \quad + e\,C^{( )} =$ (0 0 0) implies that $_1 = e_2 = \quad = e = 0$ Othe wi e the olut ns f rm a l early de pende t et th t is, th re exi t numbers e_1 e e n t ll ze uch that ${}_1C^{( )} + e\,C^{( )} + \quad + e\,C^{( )} = (0 \; 0 \quad 0)$ A et f solution i a maximal lin arly independ t s t if the et i line- arly independ t an l if a et f med l y adding any ther sol t n of (6) i l early dep nd nt If the r nk of the matrix A of (6) i then the num ber of sol t n in a m xim l ind pe dent et i $n - r$ E ery soluti n of (6) a l ear mbina ti n $e\,C \quad + e\,C^{( )} + \quad + e\,C^{( )}$ of the so- luti n in a ma mal i depende t t In the ex ample (2) the c r p ding h m geneou y t m is

$$
\begin{aligned}
2x_1 - \quad x_2 \qquad - \quad x + 2x_5 &= 0 \\
x_1 + 3 \quad _2 + 4 \quad - 3x \quad - \quad x_5 &= 0 \qquad (8) \\
3x_1 + 2x_2 + 4 \quad _3 + 2x \quad + 3x &= 0
\end{aligned}
$$

Th ra k f the m tr x A f (8) i 3 Thu th e are $5 - 3 = 2$ sol t ns n ma mal li early i depend nt t. They n be g en s $C^{( )} = (-4 \; -8 \; 7 \; 0 \; 0)$ a d $C^{( )} = (-3, \; 1 \; 0 \; -1 \; 3)$ E ry ol t on f (8) i g en by $e\,C^{(} + \; C^{( )} =$ $(-4e \; -3 \; _2 \; -8e + e \quad 7 \; _1 \; -e \quad 3 \;)$ f arbi trary e nd E ery solut on f the r g n l sy tem i gi en by $(\frac{9}{7} - 4 \quad -3 \quad \frac{8}{7}{}_1 - 8e + 7e \quad -\frac{2}{7} - e \quad 3 \;)$ I the e mple (7) the rank f the mat x i 2 nd the e i $3 - 2 = 1$ sol ti n in a maximal li early indepe de t s t It ca b gi a $C = (-10 \; 16 \; 17)$ a d e ry sol ti n f (7) s a mult ple of C

If the y t m f quat n (1) has a sol t n then t h s r t o l solut n Th s m n that the is a soluti wh ch s bt n d by employi g nly th rat al perat of add t o ubt ac t o multipl c t n and d is n n th c effici nt f the ystem Th p rt ula l t n a well s th li early d pe de t solut n of th c rre- p d g h m g eo yst m ca lw y b se- lected at n lly Th s e dent si ce the per t s pe f rmed n the ystem t obta n a sol t ar r t l pe at ns S EQUATIONS THEORY OF POLYNOMI L SYSTEMS OF EQUATIONS

[R A B]

Linearity

Th relat n h p th t e i t betw en two q ant t wh ha g ne f them pr d c s a d r tly p po t al h g th oth Thu mpli fie ha good l ity wh n d bl g of its nput g l t e gth always d ubl the tp t sig al str gth An l tr n t b h g d l n ar ty wh do bli g f th t ta s t l g d lt g rs t d uble the i st t s l f pl t c rrent

$$\begin{aligned} x_{1} + d_{1} {}_{+1}x {}_{+1} + d_{1} {}_{+2}x {}_{+2} + \quad & + d_1\, x = e_1 \\ x + d_2 {}_{+1}x {}_{+1} + \quad & + d_2\, x = e \\ x + d {}_{+1}x {}_{+1} + \quad & + d\, {}_n x = e \\ & 0 = e_{+1} \\ & 0 = e_m \end{aligned} \qquad (3)$$

If $e_{1} = e = \quad = e_m = 0$ then the olutions of the system can be obtained by choosing arbitrary values for the unknowns other than

$$x \quad x \quad\quad x$$

and solving the equations in turn beginning with the last equation for

$$x \quad x_{-1} \quad\quad x_{m} \quad x$$

When the system has solutions it is said to be consistent If any one of e_{1} e e_m is not zero then the equations do not have a solution and are inconsistent In the example (2) the system is equivalent to the system

$$\begin{aligned} x_1 + 3x_2 + 4x_3 - 3x_4 - x_5 &= 4 \\ x_2 + {}^{8}\!/\!_{7}x_3 - {}^{5}\!/\!_{7}x_4 - {}^{3}\!/\!_{7}x_5 &= {}^{8}\!/\!_{7} \\ x_4 + {}^{1}\!/\!_{3}x_5 &= -{}^{2}\!/\!_{3} \end{aligned}$$

Arbitrary values c_5 and c_3 can be chosen for x_5 and x respectively and the equations can be solved successively for x x_2 and x_1

The operations used in reducing system (1) to system (3) can be most effectively performed on the rows of the matrix of the system

$$A = \begin{pmatrix} a_{11} & a_{12} & & a_1 & b_1 \\ a_{21} & a_2 & & a_2 & b_2 \\ \\ a_{m1} & a_m & & a_m & b_m \end{pmatrix} \qquad (4)$$

and they are precisely the elementary row transformations of a matrix (*see* MATRIX THEORY) The matrix (4) is called augmented matrix of the system and the matrix

$$A = \begin{pmatrix} a_{11} & a_{12} & & a_1 \\ a_{21} & a_{22} & & a_2 \\ \\ a_{m1} & a_m & & a_m \end{pmatrix} \qquad (5)$$

is called the matrix of the coefficients The rank of a rectangular matrix is defined and the method for determining the rank is given in the article on matrix theory A necessary and sufficient condition for the existence of a olution of system (1) is that the rank of the augmented matrix A be the same as the rank of the matrix of coefficients A In the example (2) the rank of the augmented matrix

$$A = \begin{pmatrix} 2 & -1 & 0 & -1 & 2 & 2 \\ 1 & 3 & 4 & -3 & -1 & 4 \\ 3 & 2 & 4 & 2 & 3 & 2 \end{pmatrix}$$

as well as the rank of

$$A = \begin{pmatrix} 2 & -1 & 0 & -1 & 2 \\ 1 & 3 & 4 & -3 & -1 \\ 3 & 2 & 4 & 2 & 3 \end{pmatrix}$$

is equal to 3 Therefore the system is con i tent, and has the solutions given earlier

If $m = n$ in system (1) and if the determinant $|A|$ (*see* DETERMINANT) of the matrix of the coefficients A is not zero then the sy tem (1) has a unique solution which can be obtained by Cramer s rule which gives the values of the unknown x_1 x_2 x as the ratio of two determinants Specifically Cramer s rule gives

$$x_1 = \begin{vmatrix} b_1 & a_{12} & & a_1 \\ b_2 & a_{22} & & a_2 \\ \\ b & a_{2} & & a \end{vmatrix} \Big/ |A|$$

$$x_2 = \begin{vmatrix} a_{11} & b_1 & a_{13} & & a_1 \\ a_{21} & b_2 & a_{23} & & a_2 \\ \\ a_{1} & b & a_{3} & & a \end{vmatrix} \Big/ |A|$$

$$x = \begin{vmatrix} a_{11} & & a_{1\,-1} & b_1 \\ a_{21} & & a_{2\,-1} & b_2 \\ \\ a_{1} & & a_{-1} & b \end{vmatrix} \Big/ |A|$$

In every ca e the determinant in the denominato is $|A|$ and for the value of the unknown x th determinant in the numerator is the determinant o the matrix obtained from A by replacing the it column of A by b_1 b_2 b If $|A| = 0$ in th case of n equations in n unknowns the system ma either be incon i tent or it may have infinitel many solutions In the example

$$\begin{aligned} x_1 - 4x_2 + 5x_3 &= 6 \\ 2x_1 - 11x_2 + 10x_3 &= -1 \\ 4x_1 - x_2 + 5x_3 &= 0 \end{aligned}$$

$$|A| = \begin{vmatrix} 1 & -4 & 5 \\ 2 & -11 & 10 \\ 4 & -1 & 5 \end{vmatrix} = 45$$

and the unique solution is given by

$$x_1 = \begin{vmatrix} 6 & -4 & 5 \\ -1 & -11 & 10 \\ 0 & -1 & 5 \end{vmatrix} \Big/ 45 = -{}^{285}\!/\!_{45} = -{}^{19}\!/\!_{3}$$

$$x_2 = \begin{vmatrix} 1 & 6 & 5 \\ 2 & -1 & 10 \\ 4 & 0 & 5 \end{vmatrix} \Big/ 45 = {}^{195}\!/\!_{45} = {}^{13}\!/\!_{3}$$

$$x_3 = \begin{vmatrix} 1 & -4 & 6 \\ 2 & -11 & -1 \\ 4 & -1 & 0 \end{vmatrix} \Big/ 45 = {}^{267}\!/\!_{45} = {}^{89}\!/\!_{15}$$

If in system (1) $b_1 = b_2 = \quad = b_m = 0$ the system

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \quad & + a_{1n}x = 0 \\ a_{21}x_1 + a_{22}x_2 + \quad & + a_{2n}x = 0 \\ a_{m1}x_1 + a_{m2}x_2 + \quad & + a_{mn}x = 0 \end{aligned} \qquad (6)$$

called h m ge eou S nce the augme ted matrix f (6) d ff rs from th matrix f the c efficients by an add ti al c l mn of ze the e matrices al s h e the ame r k so that a hom geneou system lway co i tent It has the b i l u n 0 x = 0 x = 0 which i all d the tri l sol t A y l t n with t l t e ≠ 0 is c lled no t i ial A h m ge eo system of m equat in n unknown ha a n m al sol ti n if a d ly if the rank of th mat i f coeffi ts A is less than n In particular if m l th n th ra k of A is at m t m and the tem has a tri ial sol t n Furthe if m = the syst m h a no t i ial sol t on if a d ly if th det rminant $|A| = 0$ In th sy tem

$$\begin{aligned} 3\ _1+4\ -\ 2x &= 0\\ -_2x_1+3\ -\ 4 &= 0\\ 5\ _1+\ _2+\ _4x_3 &= 0\\ -9\ _1+5\ _2-10x_3 &= 0 \end{aligned}$$

the rank f

$$A = \begin{pmatrix} 3 & 4 & -? \\ -2 & 3 & -4 \\ 5 & 1 & 2 \\ -9 & 5 & -10 \end{pmatrix} \tag{7}$$

is 2, so th t th sy t m (7) ha a no tri l lu tio The k f A i seen t b 2 by pe f rming elementary w tr n f rmat n A to edu it to th f rm

$$\begin{pmatrix} 1 & \frac{4}{3} & -\frac{2}{3} \\ 0 & 1 & -\frac{?}{17} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

System (6) eq i le t t th ystem

$$+\tfrac{4}{3}\ -\ \tfrac{2}{3}\ = 0$$
$$_2-\tfrac{1?}{17}x_3 = 0$$

The sol tio a g n by $x = -10/17$ $x_2 =$ 16 1 ₃ = ₃, h s a bit a ly h number

In the ev nt th t li e r sy tem (1) h i fi nit ly many sol t on they c b g e as w do in the ampl (2) o lt rn t ly a fi ite numbe of sol t on c b l ted n t rm f h h all sol ti n n be tly bt ed in n fixed l t f (1) c ll d p rt ula soluti n. In th ex mple (2) $x = \frac{9}{7}$ $x = \frac{8}{7}$ 0 x $-\frac{2}{3}$, = 0 s pa ti ul r sol t o If th sy t m (1) i c te t, every s lut o s f x, + c wh re c $x = c_2 + c$ ( ) s fi ed p rti l r sol tion of (1) and c ( ) c ( ) c, is any sol t on f the rrespo ding homogeneo sy t m (6) By i tu f th e lt it uffi t t e t g t th sol ti n f th homogeneou y t m (6)

Let C = (c ( ) ( ) c ( )) nd $C^{( )}$ = mogeneo sy t m (6) writte) be sol t o f the h C + C = (( ) + c ( ) n t ples The ( ) + ( ) eC + ( ) i th m of th l t d (c) whe e

a fixed number i a scalar m ltiple f the solution $C^{( )}$ It i evident that a y l e r combinatio $e\,C^{( )} + {}_2C^{( )} + \quad + \ C^{( )}$ of olutions $C^{( )}$ C) $C^{( )}$ of (6) is gain a solution of (6) A et of solut n $C^{( )}$ C) $C^{( )}$ f the hom ge eous y tem (6) i called a l nearly independe t et if ${}_1C^{(1)} + e\,C^{(2)} + \quad + e\,C^{( )} =$ (0 0 0) impl e that $e = e = \quad = e = 0$ Otherwi the lutions f rm a line ly dependent et that i there exist n mber e_1 e e not all ero uch that $e\,C^{( )} + e\,C^{( )} + \quad + e\,C^{( )} = (0\ 0 \quad 0)$ A t f sol t i a m x mal li rly ind pendent s t if the et i li early indepe dent and if a t f rmed l y add g a y ther sol t n of (6) i lin rly d p dent If the r k of th matrix A f (6) i th n the n im ber of luti n a ma mal independ t et i $n -$ F ry sol t n of (6) is a l ear c mbina ti n $C^{( )} + e\,C^{( )} + \quad + \ C^{( )}$ of the sol t ns n a m mal i dependent set In the ex ample ( ) the rresp d ng h m geneou sy tem is

$$\begin{aligned} 2x_1 -\ x_2 \qquad\ -\ x_4 + 2x_5 &= 0\\ x_1 + 3x_2 + 1x\ -\ 3x\ -\ x &= 0\\ 3x\ + 2x_2 + 1x\ + 2x\ + 3x_5 &= 0 \end{aligned} \tag{8}$$

The rank of th matri A f (8) i 3 Thus there re $5 - 3 = 2$ sol t n a maximal lin ly i d p nde t et They can be gi en s $C^{( )} = (-4\ -8\ 7\ 0\ 0)$ nd $C^{( )} = (-3\ 1\ 0\ -1\ 3)$ E ery sol t n f (8) i g e by $C^{( )} + C^{( )} =$ $(-4\ \ -3\ \ -8\ \ +e\ \ 7\ \ -e\ \ 3\ )$ f r rbi trary e a d e E ery sol ti f the rig l ys tem is g e by $(\frac{?}{7} - 4e\ -3e\ \ \frac{?}{7}{}_1 - 8e_1 + {}_2$ $7e\ \ -\frac{?}{3} - e\ \ 3\ )$ In th e ample (7) the nk of the m tri 2 d there i $3 - 2 = 1$ solut n i a m xim l l e rly nd pend t set It can be g en as $C^{( )} = (-10\ 16\ 17)$ nd every solut n of (7) i a m ltipl f C)

If the y tem f qu t s (1) h s a sol t the t h a r t l sol tio Th s me ns that the e is sol t n wh ch obtai ed by mpl y g nly th at l per t n f dd t o bt ac ti n m lt pl ti a d di o th co ffi e t of the y t m The p tic l r ol tio a well as th li rly nd pe dent sol t o f th c respo d g h moge eo sy tem c n lw y be e l ted ti lly Th i e de t s c the pe a t s perf rmed n the y t m t btai n sol t o a r t o l op at ns *S* EQUATIONS THEORY OF POLYNOMIAL SYSTEMS OF EQUATIONS

[R A B]

Linearity

Th r lat n h p th t i t b tw two q tit e whe ch g in e f th m p od s a d ectly p p t l ch g i th ther Th ampl fi h g d l a ty wh n d i bl g of it np t gnal st gth lway d bl th tput gn l t gth A el ct t b h g d l nea ty when d bl g f the i t t t l g d lt g rv t d bl th i ta t e l e f pl te e t

In television uniform linearity of scanning is essential for uniform spacing of picture elements in each horizontal line and uniform vertical spacings between scanning lines Poor linearity causes the picture to be compressed or stretched in some area so that circles of te t patterns become egg shaped or even more greatly distorted [J MR]

Linen

A widely used cloth made from flax fibers Linen is noted for its evenness of thread fineness and density Its uses include garments tablecloths sheeting towel and thread

The flax plant which supplies the fiber needs a short cool growing season with plenty of rainfall (see FLAX) The U S S R leads the world in growing flax for fiber The manufacture of the fiber into fabric requires unusual care throughout each proce s in order to retain the strength and beauty of the fiber

Processing the fiber Seeds and leaves are removed from the stems of the flax plant by passing the stalks through coarse combs a process called rippling Bundles of stems weighted down with heavy stones to ensure complete immersion are then steeped in water The wetting allows the tissue or woody bark surrounding the hairlike flax fibers to decompose thus loosening the gum that binds the fibers together This decomposing or fermentation is called retting

After removal from water the stems may be spread out on the ground for a week or more After the woody tissue has become dry it is cru hed by fluted iron rollers After this breaking operation there remain only small pieces of bark called shives The shives are removed by means of rotating wooden paddles thus finally releasing the flax fibers This operation can be done either by hand or with machinery The simple combing process known as hackling straightens the flax fibers ep arates the short from the long staple and leaves the longer fibers in parallel formation For very fine linen hackling is usually done by hand and is repeated a finer comb being used with each hackling treatment Coarse linen is hackled by machine

Properties of flax fiber Under a micro cope the flax fiber shows hairlike cylindrical filaments with fine pointed ends The filaments are cemented together at intervals in the form of markings or nodes by a gummy substance called pectin (see PECTIN) The long flax filaments contain a lumen or central canal The fiber resembles a straight smooth bamboo stick with its joints producing a slight natural unevenness that cannot be eliminated Chemically the flax fiber is compo ed of about 70% cellulose 25% pectin and the remainder of woody tissue and ash (see CELLULOSE) From such fibers linen yarns are produced that have a smooth straight compact and lustrous appearance See FIBER NATURAL TEXTILE [M D P]

Bibliography See AGRICULTURAL SCIENCE (PLANT)

Lines of force

Imaginary lines in fields of force whose tangent at any point give the direction of the field at tha point and whose number through unit area perpendicular to the field represents the inten ity of th field The concept of lines of force is perhaps mos common when dealing with electric or magneti fields

Electric lines of force These are lines drawn t represent or map an electric field graphically i the space around a charged body They are of grea help in visualizing an electric field and in quantita tive thinking about such a field The direction of an electric line of force at any point is drawn parallel to the direction of the electric field intensity E at that point The quantitative convention is that the number of electric lines of force drawn through an imaginary unit area of surface perpendicular to the field shall be numerically equal to E at that area From this quantitative convention and using the rationalized mks system of units q/ϵ_0 lines of force originate on a positive charge q (in coulombs) and a like number terminate on a negative charge q of the same magnitude Here $\epsilon_0 = 8.85 \times 10^{-12}$ coul²/newton m² is the permittivity of empty space See ELECTRIC FIELD

Magnetic lines of force A magnetic field of strength H may also be represented by lines called lines of force The number of lines of force per unit area of a surface perpendicular to H is numerically equal to the value of H The lines of magnetic force due to currents are closed curves as are the lines of magnetic induction Magnetic lines of force due to magnets originate on north poles and terminate on south poles both inside and outside the magnet See MAGNETIC FIELD [R P WI]

Bibliography R P Winch *Electricity and Magnetism* 1955

Link

An element of a mechanical linkage A link may be a straight bar a disk or it may have any other shape simple or complex It is assumed for simple analysis to be made of unyielding material—that is its shape does not change A link is capable of turning about an instant center The frame or fixed member of a linkage is one of the links whether the frame is fixed relative to the earth or fixed relative to a movable body such as the chassis of an automobile By this definition auxiliary members of mechanisms such as belts springs and other flexible connectors and liquid columns in hydraulic systems are not links [E S F]

Linkage genetic

The presence of numerous pairs of genes in the same chromosome or homologous pair of chromosomes Two or more gene differences do not egregate independently into separate cell nuclei when they are located in homologous chromo ome They remain in their original combinations unle s a mutual exchange of equivalent chromos mal seg

nt occur bet ee p red homologs in a proce s own as cro ing er See RECOMBINATION GE ETIC SEX LI KED INHERITA CE. [D D P]

inkage mechanical

set of rigid bod es, called links joined together t pivots b mea of p s q alent device bod is n idered to be rigid if f p actical urposes the distances between points on the body not change Li kages are used to tran mit power nd inf rm ti n Th y may be mpl yed to make a oint the linkage follow a prescr bed curve re- ardl f the inp t mot on t the li k ge They re sed to p od c an a gular or l near d pl ce- ent f( ) here f( ) a g en f nct n of a d placement

If the links are bars the l kag termed a bar linkage. In first app o mat s a bar may be treated as a tr ght l e segme t a portion f a curve, and a p vot m y be t e ted as a common point on the bars connected at the p ot A m n f rm f bar linkage i then one for wh ch the ba re estri ted t a gi en plane such as a four bar linkage (F g 1) A body pi ted t a fixed base a d t ne or m e oth l ks is a crank. 4 cra k 4 in Fig 1 r t tes, link 2 (lso crank) scillates b ck a d forth Th f ur b r link thus tran forms a r tary m ti int a oscillat ry o e r vi e s Link AB marked 1 is fi ed. Link 2 m y be replaced by a lide 5 (Fig 2) As e d D of crank 4 rotates pi t C describes the same curve a befo e The sl der m es in a fixed groove

A comm nly occurring a i tion f the f ur bar linkage is th link ge u ed in ec procating en

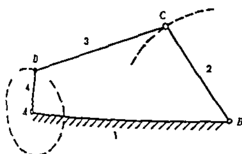


Fig 1 Fou -b l k g

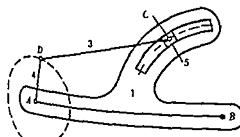


Fig 2 Eq ival t of f -b l k g

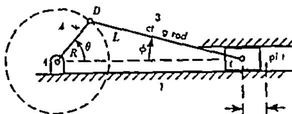


Fig 3 Sl d -cra k mech m

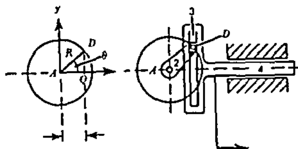


Fig 4 Scot h y ke

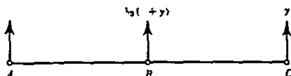


Fig 5 Add t w th a l

gines (Fig 3) Slider C is th p ston in a cyli der l k 3 i the nnecting rod a d li k 4 is the crank Thi mechani m t an f rms a line i to cir ular motio or e The str ight sl de i li with the rank enter is equi alent to pi ot t th end f an infin tely l g l nk Let R be the le gth of the nk, L th length of the co ecti g od wh le θ and ϕ de te the a gles of the c ank nd rod (F g 3) Let x d ot the coord nat f the pi ot C measured s that $x = 0$ whe $\theta = 0$ Le gth L normally d minates rad u R whe c the f ll wi g app oximat rel ti n h lds

$$x = R(1 - \cos\theta) + \frac{R^2}{2L} \sin^2\theta \qquad (1)$$

A Sc tch y ke i employed t c n ert ste dy r t ti int s mple harm ni m tion (Fig 4) The a gle of the a k 2 with espect to th h r izo tal de ted by θ a d the oord nate of the sl de 4 by x If R aga n de ot the length f th cra k th foll wi g hold

$$x = R \cos\theta \qquad (2)$$

I c mput m ha sm sl de 3 can be m ed al g the c nk th t the mpon nt of a ect c n b bt i ed mecha cally

A lever s n rmally u d stood t be a ba con nected t th e th link A lev s ften sed for dd t (F g 5) P nt B t the c nte of l e AC It med th t x d y ar ume i cally m ll c mpa ed t the l gth of th l er

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Section through th lowe l p f ma (From R. O Greep d H st logy McG w-Hill 1954)

Cheeks. S nc th m th peni g of mammal ll in f o t of the j ints f th jaw reg on created m ea h d kn wn a th heek. Ea h is contin ti n b ckw rd f th l ps and is es en tially sim lar in tru t Some rodents d Old World m keys ha expa ded thes p ces t heek po hes wh h re sed f the t mpor ry st rag d carri ge f food. The pocket g pher ha e p e po ches th heek regi n, but th m ta they ar ha l ed a pe g onto th external rf ce d t int th m th.

Morphology Struct rally a l p pl te f l untary muscl th ter sid rfa ed with kin and th m r d with a m memb At the red m gi betw these rf es there s a z n that is tran t l between these tw overi g Th km f th t d f th l p i qu t typ al, th thin p d rm wh h h were both p qu d c rnified Beneath th piderm l cover lie hai f ll les weat gland d seb eou glands Cent lly with n th l p a pl t f k letal m scl wh h f rmed mostly by th b cula m scl Slip f m l sert m g th on ec tiv ti bundles f th k d thi lat end th k m b l Hen th m scl her be l gs to th fa l muscles f exp es th mi met m les Th n er d f th l p a typ l cou memb Its t t fi d quam ep th li m m kedly th ker th th piderm but t rn fied Thi typ f ft ep th l um ha art t f w t f es bject t frict d not bsorptiv C p f ded l b l gl d oc d p i wh t may be lled bm cosal l Th se tio l my m cu a d ther d t pen t th est b l Th red ma gi n termed t tru tur betw en th ter d er rf es Th ep th l um tr n l ent T ll as cul p p ll f nert t dent the ep th l m f t w d th f T y blood essel exten l t thes p p ll d th ta ned blood h w th gh th g g th l p ed l S m l l rs end gs a l ght los t th f so th t the m g l gu h ghly sen t Cl d f th zon d the soft

pithelium ha t be m i t ed frequently l y wip i g with the t g e Acc r l gly the labial margin i s bject t happ ng r ra k g

Development Th low r lip a d j w de elop fr m the fu i n of tw c mponent th m nd l lar processes wh le th upper lip a d j w dev l p fr m four the tw m xillary a d tw med na l proces es Th pper l p is m e pr e t mi haps in devel pm t th c mm nest f wl h i "h e lip At times thi cl ftl k d fect l es the upper jaw bo e and th m be ml ed with left pal t Lip be me parat tities wh n the ep thel m f ach primit e jaw region gr w i wa d a a plate and then clea es in two tl ereby prod cing the estib le d par t g the lip fr m the g m S ORAL GLAND [L.B.A.]

Lipid

O e f a la f compound whi h t in l ng h n al ph t hyd oc bons (cycli o acylic) a d ther de i ati es such a ac d (f tty a d) al oh l am es am o alc hol a d ald hydes Th p ese f the l ng l ph t chai the ch t i ti compo t of l pid co fe d t ct l bil ty pr pert es n the mpl r members f th l f t lly occ rr g compo d Th s led t th t dit al d fi ti n f l pid ub t es whi h a e l ble in w ter b t soluble i f t sol ent s h a th r chl f rm, d benz e H weve those l p d (p rticul ly glycol p d d phosph l p d) wh h cont n pol r c mpo ent in the m lecule m y be i soluble in thes sol ent a d me are even sol bl n w te (s SOLVE T) Most f th phosphat des a good em l fyi g g t S e EMULSIO

Classification Th l pid ar g erally cla i fied t th f ll wi g gr p

A S mple l p d.
1 T gly rides f t d oil a e fatty d esters f gly l E amples la d, c rn l, tt ed il d butter
2 Wa es r fatty a d ester of l ng-cha n l h l E mples r beesw x, perm c ti, nd carn b w x.
3 Ster id r l p d deri ed f om parti lly mplet ly hydr gen ted phen th e Ex mples r h lest r l d ergosterol.

B Complex l pid
1 Phosph t des r phosph l p d l p ds wh h co ta phosph ru and n many i t e tr gen. Examples lec th n, ph l n, a d phosph t dyl inos t l.
2 Gly l p d l p d which t in bohydr t es d es Examples e t l glycodes e b os des d pl t phytogly o l p d
3 Sph g lip d e lip ds conta ing th lo g ch in m al h l sph gosine d its d ri t es E mples phing my l eram des d ereb os des

Th cl fic t n heme t rigid s e phi g l p d e f und whi h co t ph ph ru

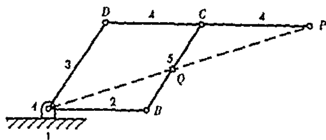


Fig 6 Pantograph

Lever with a fixed pivot (fulcrum) are particularly u eful for amplifying or attenuating linear di placements and forces

The pantograph shown in Fig 6 is a five link mechanism employed in drafting to magnify or reduce diagrams As point Q on link 5 describes a curve point P on link 4 will describe a similar but enlarged curve Here $ABCD$ is a parallelogram Pivot A is fixed

A mechanism compo ed of six links introduced by Jo eph Whitworth (1803–1887) makes the return stroke of a body in o cillatory linear motion faster than the forward stroke Universal joints for transmitting motion between inter ecting axes and e capements permitting rotation about an axi in one direction only are examples of the many kinds of linkages used in machines However complicated linkages are becoming obsolete becau e of the ease with which information and power can b transmitted by electrical hydraulic and pneumatic mean [R O]

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Linoleum

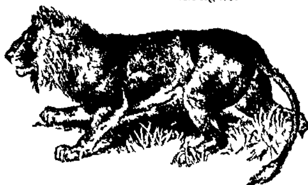
A floor covering made by applying a mixture of gelled lin eed oil pigments fillers and other materials to a burlap backing and curing to produce a hard resilient sheet The surface may be further dec rated by printed patterns The term is al o applied although incorrectly to similar resilient floor coverings made of other resins or related materials S e DRYING OIL [F SD]

Linseed oil

A product made from the seed of the flax plant (*Linum usitatissimum*) by crushing and pressing them either with or without heat After the lin eed oil is extracted it is formulated either raw or boiled in various grade and with vari us drying agents such as *litharge minium and zinc sulfate* Its most common uses are as the vehicle in oil paints and as a component of oil varni hes after a longer p riod of boiling and oth r preparation as a printing and lithographic ink ba e in the manufacture of oilskin raincoats oilcloth and linoleum and in some soaps Oil cake the residue of the cru hed seeds is a protein rich material u ed for cattle feed Most linseed raised for oil comes from Argentina Ru ia and India with le er quantities from the north central United States and Canada It was first used as a drying oil in the twelfth century with the *introduction of oil painting* See DRYING OIL FLAX SURFACE COATING [F CO]

Lion

A large carnivore *Felis leo* of the family Felidae now limited to outhern and central Africa At one time it was found over much of A ia and outhern Europe The male lion may attain a weight of 600 lb and a length of 11 ft including the tail Females are somewhat shorter and much lighter



The African l on *Fel leo* le gth to 8 ft (F om P M Du con d Cassell s Natu al History Cas ell 1883)

Because of relentle s hunting lions are constantly being reduced in numbers and are lo ing territory They live in group called prid an l show a degree of cooperation in the ecuring of food and rearing of the young not practiced by other cat Mo t of the work of ecuring food f r the pride is done by the female Lions are greatly haras ed by a host of smaller animals that try to steal part of the kill when the lion have succeeded in the hunt *See* CARNIVORA [J D R]

Lip

A fleshy fold above and below the entrance to the mouth of mammals Even the l wer ertebrate with movable jaws such as fi he amphibian an l most reptiles have fold of skin external to the jaws and teeth The e f ld c vered uperficially with epithelium are usually oft and u p rted internally by connective ti sue By ntra t in turtles birds and the lowe t mammal (monotremes) the epithelium i cornified and hard o a to form a beak or bill Neverthele nly th typical mammal (mar upial and placental mammal) po es a highly developed ty e f true li The e are eparated by deep cleft fr m the jaw an l are made m bile by containing m cle l el nging t the facial group The eparating left r p c n stitutes the ve ti ule of the mouth The in rea ed size and mol ility of the lip of mammal are adapted to such functi ns a king drinking gra ping food and h lding it again t the te th Th opening int the m uth is xpan le r tricted at will The li of man are i t to im rtant u e in producing articulate peech and th s a l in facial expre i n

fectio thro gh th l w l p f m (Fr m R O G p ed Hst logy M G w-H Jl 1954)

Cheeks. S n e the m uth open ng of mammals lies w ll m fro t of the joints f the jaw a region is ere ted n each side known a th ch ek. Ea h i a e t u tio ba kwa d f th l p and s essen tially sim l m truct re Some rodent and Old W rld m nke h e xpanded th e sp ces into cheek p uches h h e ed f r th temporary st g and carr ag of food The pock t gophe s ha e xpa e po ches i th cheek reg n but in th n t n e th y ar ha r l ned a s pening o to the e t rnal rfa e a d not nto the m uth

Morphology St tu ally l p a plate f ol unt ry m s l th te de urfa ed w th kin a d th inne d with m c u memb ne At th red m rgin b twe these u faces th ts z n th t s tran iti nal between these two c vet ngs Th ki f th te d f th l p q ite typ al th th n pid rm s wh h however both p qu and m fi d B n th th p derm l o r fi h f ll l sw at gl d nd eba eo s gl d Ce t llv w th n th l p pl t of k le- t l muscl wh ch i f rmed mo tly by th o b l r muscl Sl ps f m l ert m ng the nnec t -s u bu dles of the k n and th s l t tend th kin m bile Hen the m le here b long t the fa l m l s f xp s on th m m t e mu l Th n r d of th l p a typ l m o m mb e Its stratified g m p the- li m i m k dl th k th th p d rm s but s n t e m fi d Tl s typ f ft pithel m s ha a t t f w t u f e bject t f ct n and n t b pt Gro p of r ded lab l gl nds u deep in h t may b alled ubmu osal l ye Th er t n a l my m u d the d t ope t th t bul The red marg n n f rmed t t ct b t the t r and inner f c Th ep th l m i t a l ent Tall s l p p ll e f n t e t ue i d nt th ep thel m f t w d the u f T y blood s l ext d nto the p p'll nd th t ned bl od h w tl gh th g g th l p d ol r S m la ly nerv d g br ght l e t th u fa tl t th m rg n l r g o h ghl t Cl d ab t n tl n d th fi

epithelium has to be m i tened frequentl) by wiping with the t gue Accord ngly tl lab al margin is subject to cl pping or cra king

Development Tl e lower lip and jaw develop f m th fu ion of two component the mand bular proce es while th upper lip and jaw devel p from four the two m axillary and two median na al proce e The upper l p i more pr ne t m hap in de el pment the commonest of wl i h i hare l p At times th cleftlik defe t in f e the uppe jaw bone and then may be e mbined with a left p late Lip become eparate entiti when the ep il eli m of e ch prim ti e jaw r g n g ows inwar l a a pl te and then cl a e in two thereby p od c ng the vestibule and ep rat ng the lip from th gum *Se* ORAL GLAND [L.B A]

Lipid

One of cla of comp und which contain l ng ch in aliphatic l ydroc rbons (cycl c o acylic) and their de ti es uch s a ids (fatty acid) lc hols am es amino alcohol and aldehydes Th presen e f the l ng liph t cl ain as the ch racteri tic c mponent of lip d o fers di tinct ol b l ty pr p t e on the s mple members of th cla of naturally occurring compo nds Thi led to the t ad ti nal defin tion of lip ds a sub tan es whi h in oluble in water but s lubl in fat l e ts su h as ethe chl roform and be zene H we er those lipid (particularly glycol p d and phosphol pids) whi h c ntain pol r c mponents in the m lecule may b ins luble in these sol nt and me are even s l ble in wat r (s e SOLVENT) M st f th ph phat des are good em l fy ng age ts *See* EMULSION

Classification Th l p ds are ge erally cla fi d into th f llowi g gr ups

A S mple l pids
1 T iglycer d s o fat and ils a e fatty d e te s f glyce ol Ex mples ar l rd corn il tton ed oil and butte
2 W e are fatty a id est r of l ng-cha n alc h ls E ampl are beeswax permaceti and c rn b w x
3 Steroids e lip d de ed f om p rt ally o compl tely hyd ogenated ph n nthrene Examples are chol te ol and e gosterol

B C mpl x l pids
1 Ph phatide r ph sph l p d a l pids wh ch o tan ph ph ri s d in many n tan es n tr g n Example are lecith n c phal n d ph ph t dyl n sitol
2 Glyc l pid are l pid wh h ontain ca bohydrat r idue E amples a t l glyco s d e eb d s and pla t phyt glyco- l p ds
3 Sph n ol p d ar l p ds taining the long ch n amin al oh l phin osine and it der ati e E mple re sph gomyel n c mides and br d

Th l fi at o s h me s n t rıg d n e phing l p d r f u d wh ch conta n pho ph r

and carbohydrate and glycolipids which contain phosphorus Those lipids not included in the above groupings are of the chemically simpler type and include the fatty acids alcohols ethers such as batyl and chimyl alcohols and hydrocarbons such as the terpenes and carotenes

The fatty acids found in lipids may be saturated or unsaturated cyclic or acyclic and contain sub stituent such as hydroxyl or keto groups They are combined in ester or amide linkage

The alcohols likewise may be saturated or un saturated and are combined in ester or ether link ages in the case of $\alpha \beta$ unsaturated ethers these are best considered as aldehyde derivatives

The amino alcohols found in lipids are linked as amides glycosides or phosphate esters Sphingo sine is the amino alcohol found in animal tissues and phytosphingo ine is its equivalent in the plant kingdom One long chain diamine (necrosamine) has been isolated from the lipids of the bacterium *Escherichia coli*

Occurrence Lipids are present in all living cells *but the proportion varies from tissue to tissue* The triglycerides accumulate in certain areas such as adipose tissue in the human being and in the seeds of plants where they represent a form of energy storage The more complex lipids appear to be more nearly structural elements and occur in the membranes of cells and of special bodies within the cells More active tissues generally have a higher complex lipid content for example the brain liver kidney lung and blood contain the highest concentration of phosphatides in the mam mal Fish oils are important sources of vitamins A and D and seed g rm oils contain quantities of vi tamin E The vitamins K occur chiefly in plants and microorganisms and carotenoids are widely distributed in both the plant and animal kingdoms Waxes are found in insects and as protective agents on plant leaves and the cuticles of fruits and vegetables (for instance the bloom on grapes and plums) Soybeans are used for the commercial preparation of phosphatides

Extraction Many of the lipid particularly glycolipids phosphatides and steroid ester are present in the tissue in association with other cell components such as protein The nature of the linkages in these complexes is not fully understood although they are most certainly not covalent Combinations of lipid and protein like lipopro teins and proteolipids ha e been isolated from sources such as blood serum and egg yolk For the efficient extraction of lipids from tissues these complexes must first be disrupted and this is usu ally accomplished *by dehydration procedures such* as freeze drying or acetone extraction or by dena turation with alcohol before extracting the ti sue with suitable lipid solvents The u e of mixed sol vents uch as ethanol and ether ethanol and ben zene or chloroform and methanol allow disrup tion dehydration and extraction in one opera tion Partial fractionation of lipid may be effected by succes ive extractions with different sol ents

Separation The difficulties involved in the epa ration of lipids have held back progre s toward their chemical identification Prior to 1948 solve fractionations or the use of specific complexu agents such as cadmium chloride for the separ tion of lecithin were the only methods availabl Since then the use of column *chromatograph* particularly on alumina and silicic acid counte current distribution and ion exchange re ins h allowed far more rapid progress in separation an also has led to the di covery of previou ly und scribed lipids Other methods which allow electi degradation of certain lipids either chemicall (for example the use of dilute alkali to cau e pre erential hydrolysis of esters) or enzymatically ar also being used succe sfully for the separation c certain lipids *See* CHROMATOGRAPHY

Identification Most of the conventional analyt cal procedures are used in the identification c lipid samples Physical methods such as infrare and ultraviolet spectroscopy optical rotation an proton magnetic resonance studies have been used *Gas phase chromatography is playing an impor* tant part in the identification of fatty acid Par ticularly useful are paper chromatography botl reversed phase and silicic acid impregnated qual itative and quantitative methods for the determina tion of esters aldehydes carbohydrate long chai basis and the other important components of lip ids such as glycerol glycerophosphate ethanola mine choline erine amino sugars and inositol and elementary analyses for nitrogen and phos phorus The nitrogen to phosphorus ratio of a phosphatide sample has long been u ed as a cri terion of purity because carbon and hydrogen analyses on a single phosphatide species are not highly revealing owing to the pectrum of fatty acids that may be present The degree of unsatura *tion is determined by hydrogenation or iodine num* ber determination and free hydroxyl groups are expressed by the acetyl value Lipid samples al o may be hydrolyzed under a variety of acid or alka line conditions and the products investigated by paper chromatography *See* CARBOXYLIC ACID FAT AND OIL, EDIBLE FAT AND OIL NONEDIBLE GLYCOLIPID LIPID METABOLISM PHOSPHATIDE SPHINGOLIPID STEROID TERPENE TRIGLYCERIDE VITAMIN WAX ANIMAL AND VEGETABLE

[H F C R H C]

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Lipid metabolism

Lipids are compounds known as fat waxe phos pholipid glycolipid and sterols The lipid are the most concentrated source of energy for li ing organi ms yielding more than twice as much en

ergy per gr m as ca bohydr te or protei They prol g th t m food remains in the t ma h and thus d l the on et f hunger Lipid al o provide th essential fatty a id uch as l n l ic l n leni a d ar h do c and ar the m an l y which the fat sol ble vitami (A D E a d K) enter the body Th bod l p d as stored fat are s urc s of food d n fa t g and as hcutaneou f t n u late again t lo f heat Th s art cle di ıs e the utilizati n and synthe of l p d ı the m mmal

Fat digestion and absorption The dige ti n process n the intest e renders fat water l ble to fa lit te absorption through the wall of the in testin and lymph cha els

Fat d sti Little fat d gestion ccurs in the st ma h cept n nf ts In the ntesti es, the b the p n atı j e and a ecreti n fr m the intest es (the succ s e teric) re the ag nts h h d gest fat. The b le fo med by the l er nd collects in the gallbl dd r From t m t t m it d scha ged f om th g llbladd r int the in testines a d mixes w th th food Th bile c ntains pigm nts d tw bile ac ds ta roch l c and gly ach l c d The a deterg nt wh ch a t t k the ngested fat w t r l ble When the a d t nt of th st mach a d ch rged int the d ode um (th fi t po t on f th intest e) a h rm n ecr t n, ı d l rged by the d d num int the blood th s t m lat th p r to se ete pan at c ju ce The pa r at c j on tai enzym whi h dig st prote n and a bohy d e d the nzym l p e whi h by hyd oly is f the ngested fat, f rm gly er l and f e fatty d Th s acti n s ls a ded by the suc u n teri The p n re t ju e th b l nd th uc e nte u m x with the food and d gest t t f rm b j)

Fat abs ptio The d gested me l r hyl mainly ab bed t th bl d thr gh th t t n l w ll but th d g ted fat e al o ab bed thr gh ı m abl lymph h nnel These o lesce t f rm th tho a d ct, which d sch rge t t t nto l rg l lo d es ls the jug lar e ı the hest If th pa ag f bile nto th ın ı bl ked by ea n f d a e th am m l d t b ch l The stool th n b com lay col d be a e of x s f the o ps of fatty a id wh h r n t ab orb d The b le id and b le p gme t e te g the bl od by ab pt n f om th h l a e m ed by th l a d aga n d sch ged s b le t the ı t t n s Th y l t nly n rves b le p gm t nd the b l a id o t p e t the r pp a n n e ess n th blood

St ı h Fa l l d gest on of f t d e t b n e f b p e t ju c s lt n n unu ual am unt of fatty material in the tool Thi c ndition is t rmed steat rrhea

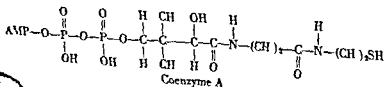
Lipids in the blood F ur f rms are rec gnized (1) t iglycerides coml inati ns of fatty acid with glycerol (2) n nesterified fatty acid (NFFA) fatty acids unc mbined with glycerol which l ave recently rece ed att nti n partic larly l ecau e of their ncrea e in diabetes (3) chol terol a com plex ter l ompo ınd wh e con entrati n in the blo d ha ıgnifi ance in hyperten ı n (4) ph phat des oml ination of fatty acid with ph s phates and lecith n Fat in the l lood exi t in tl f rm f mall dr pl t c lled chyl mic a Lipemia mean an ex e of lip d in the blood er the norm l *Se* PHO PHATIDE STEROL

Turnover of body lipids Fat n the l ody depot have a very act m t bol m They are c tinu ally bei g dep ted nd u ed up Th f tty ti e can synthe ze new fat f m carbohydrate and other s ur e mate ı ls In the teady state when total body fat is co stant the rate at wh ch fat ı oxidi ed and resynthesized ı alled the turn r rate It an b mea ured by using isotopes for ex ampl h a y water The a erag turno er ı about 10% of the t tal body fat pe day

Adipose tissue Collections f ti ı e comp ed mai ly f f t a e called adipo e ti sues In additi n to fat they l o onta n pr t n and othe b- t nces The m in sites of ad po e t ue are (1) beneath tl ski (2) a ound th k dneys nd oth r o gan and (3) in th supporti g stru tu s of the intestines the oment m me entery It w f rm rly b l e ed that d po e t ues were n ta b l cally inactive but rece t work has h wn that they are s a t ve as or more a ti e th n most si gle types of ti sue For x mple they synthe ı e fat readily f om arbohyd ate and oth r ur mate rial In add ti n they esp nd to hormo s such a n l n and gr wth ho m ne in ome in ta ce m re than the t s ue ch a the l er or mu le This metab l c act ty re d n th p ote p rti n of ad p e t e rather th n n the fat it elf

Oxidation and synthesis The body is able to x d ze fatty c ds for pu po es of ene gy pr duc t In id t n it an synthes ze new fatty acids fr m p ec rs d r ed fr m rbohydr t o pro te n Thi b osynthesi s c lled l p gene s F Ly en in est gations ha e m de th re ct ns of x d t n and l pogen s l ar Th ubject ı best nd ı d by o de ı g id t n f t

Oxid tio f high f tty acid The comple e ct o of ıdati n nd l p g nes s a mad po bl by oe zym A (CoA) whi h a omp nd f ad n mon ph phate (AMP) two m le les of pho ph te nd a mplex nitr gen deri ti call d pa tothe


Coenzyme A

CURRENT CONCEPT OF FATTY ACID OXIDATION AND SYNTHESIS

Reaction — *Enzyme*

Activation

$$\mathrm{R{-}CH_2{-}CH_2{-}CH_2{-}CO{-}OH + CoA{-}SH \rightarrow R{-}CH_2{-}CH_2{-}CH_2{-}CO{-}S{-}CoA} \qquad (1)$$

γ β α (carbons) — Thiokinase

Oxidation

$$\mathrm{R{-}CH_2{-}CH_2{-}CH_2{-}CO{-}S{-}CoA + FAD \rightarrow R{-}CH_2{-}CH{=}CH{-}CO{-}S{-}CoA + FADH_2} \qquad (2)$$

Acyl CoA dehydrogenase

Hydration

$$\mathrm{R{-}CH_2{-}CH{=}CH{-}CO{-}S{-}CoA + HOH \rightarrow R{-}CH_2{-}CH(OH){-}CH_2{-}CO{-}S{-}CoA} \qquad (3)$$

Crotonase

Oxidation

$$\mathrm{R{-}CH_2{-}CH(OH){-}CH_2{-}CO{-}S{-}CoA + DPN \rightarrow R{-}CH_2{-}CO{-}CH_2{-}CO{-}S{-}CoA + DPNH_2} \qquad (4)$$

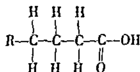
β Hydroxyacyl CoA dehydrogenase

Cleavage

$$\mathrm{R{-}CH_2{-}CO{-}CH_2{-}CO{-}S{-}CoA + CoA{-}SH \rightarrow R{-}CH_2{-}CO{-}S{-}CoA + H{-}CH_2{-}CO{-}S{-}CoA} \qquad (5)$$

Thiolase

There are five reactions concerned in the oxidation of higher fatty acids. Each requires a special enzyme and two of the reactions require cofactors as oxidizing agents which accept the hydrogens from the fatty acids. In reaction (1) activation the fatty acid is written as



in which only the terminal four carbon atoms are given. R represents a *chain of carbon atoms up to* 14 in number. The initial reaction consists of activation by combination of the carboxyl group of the fatty acid with coenzyme A, yielding an acyl coenzyme A. The enzyme is called the activating enzyme or thiokinase. In reaction (2) first oxidation two hydrogens, one each, are removed from the *α and β carbons* with the production of an unsaturated fatty acid analogous to crotonic acid. The enzyme is called *acyl* CoA dehydrogenase and the cofactor which acts as the oxidizing agent is flavine adenine dinucleotide (FAD). In reaction *(3) hydration hydrogen and the hydroxyl group* (from water) are introduced at the α and β carbons respectively, a β hydroxy acid is formed; the enzyme is crotonase. In reaction *(4)* second oxidation two hydrogens are removed from the α and β carbons of the β hydroxy acid to form a keto acid. The oxidizing agent is diphosphopyridine nucleotide (DPN). In reaction (5) cleavage acetyl CoA is split off. Thus a fatty acid two *carbons shorter than the original one is formed.* Simultaneously the shortened fatty acid combines *with another molecule of CoA at the newly formed* carboxyl group to yield a new activated fatty acid. The enzyme is β ketothiolase. The new activated fatty acid undergoes the same series of reactions and this process is repeated until the entire fatty acid molecule has been reduced completely to acetyl CoA. The fate of the acetyl CoA molecules will be discussed below. *See* DIPHOSPHOPYRIDINE NUCLEOTIDE (DPN).

The interrelation of oxidation or breakdown of fatty acids and synthesis is shown in the diagram

METABOLIC SCHEMA FATTY ACIDS

Oxidative b eakd wn

Krebs y l → CO

$C_{16}H_{32}O_2$ ——→ C_2 CoA ——→ C_4 (Ket nes)

Higher fatty acid Acetyl CoA

Synthesis

Glucose
Fructose
Lacta
P ru
Acetate
Etc.
Acetyl CoA precurso

$8C_2$ CoA ——→ $C_{16}H_{32}O_2$
H gh f f
H drog from
DPNH FADH

Oxidati n of the h gher f tty ac d uch palmitic d with 16 arb n atom yi ld ight m lec l of c tyl CoA Two fat s f a tyl CoA f rmed n th l e ar of immed at nterest

1 Oxid ti n th ough the K eb yel to carbon d x d Th K bs ycle i a c mplex y t m f nzymes The zymes i r e of r a t o c mpl t ly x di e ac tyl C A t a bon d d m s ch fa h that th y le r tituted for f rth x d t n

2 Conde sati n f tw mol c l s f a etyl CoA with th pl tt n ff of th C A f m ng o- all l k e bod s *See* KREBS CYCLE

Lipog ne The pr ces of y th of the high r f tty c ds f m n n f tty ac d p e u r is ul t ated n tle low r h lf f the diagr m Wh n gested t n a bohyd te h as gl co d fru to e y eld imple ub t n es u h l tic c d pyru i a d and et c d These pot t l precur o f t l CoA In dd t n p t also y ld t l CoA p ecu Th enzym A mole les th f rmed are u d t bu ld p th high f tt l U t l h t tim ago th proce f y th i f th h ghe f tty cid t c s d ed t b th r er of th re ct o d scus ed de o d t n Th am nzyme a d th s m f t w a med t b n l ed x pt that th e t p d d n the oppo t d ect n Fo f tty d nth two r q r m ts h d t be m t (1) A p c f a tyl CoA s neces ary th se a e l t d n th d g m (2) A r d t n nm t (hyd gen) n d ed t l d d t du ed fl e ad n d leotid (FADH) d d ed d ph phopyrid (DPNH) n eded FADH d DPNH f m h hyd g th t c d ati n f two etyl CoA m lec l n th red t atm ph r l d t th f rm t n f th fi st h gh fatty ac d (C) n th es n m ly butyryl CoA

F rth r d t n l d tep by step t l ld g p f th f tty id mole l by th mam malia h er t a chain containing 16 or 18 carbon Wh n the fatty acids reach thi length the acetyl CoA is plit off by an enzyme deacyla e yielding the free fatty acid wh ch in t rn c mb ne with gl c rol t f rm the triglyceride tl at i fat

Recent re earch w rk in fatty acid synthe i has led to th conclu n that ynthe i of fatty a id requ res a c enzyme triph phopyridine nucleo-t de in the reduc d state ($TPNH_2$) whe ea oxi dati n req ires FAD *See* TRIPHO PHOPYRIDINE NUCLEOTIDE (TPN)

Change in length of fatty acid chains Tl e fatty a id in the b dy fat depot are comp ed of l ains wl ch alway c nt in an e n number f arb n at ms The e fatty id contain the higher n m b r of arb n atoms nly namely 14 16 and 18 these are re pecti ely myri ti palm tic and te-ar c acid Tl e body readily lengthens or h rten the ha n o th t if palmiti acid (C) s fed it is p ble to h w (u ng ot pe) that the palm ti acid i lengthened by two carl ns to tear ac d (C) Con r ely it i al o p ble to h w that t ar c c d (C) may be hortened to palmitic cid (C) or myr ti acid (C) Sh rter fatty id su h a l utyric (C) cap oic (C_6) caprylic (C) and capr (C) a e f und n b tter fat but n t in th d p ts of b dy fat

Unsaturated fatty acids formation A fatty a id conta i g a double bond betw en two ca bon i c lled n un aturated f tty a d Tran form tion f om sat r ted t un at rated f tty acids cur n the an m l b dy For xample te ric cid (C) a atu ated fatty ac d i r adily conv rted to ol c d w th the me n mb r of carbon atom but nly on d ubl bond The po iti n of th double bond i ind ted by the terminol gy Δ^{9} ^{9} Th s mea n th e f ol c a d that d uble bond exi t b tween the nth and tenth rb n o nt ng f m the rboxyl nd of the l ng fatty ac d chain Th ev s tran f rm t o f u at ted fatty ac d t atu at l fatty c ds al o o u the a mal body

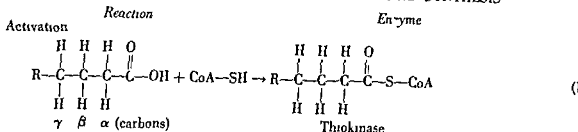
Essential fatty acids The an m l b dy is nca pabl of i t od i g a ond do ble b nd int a fatty a d It ha be n ob r ed th t if an anim l u h s a at s d pr ed f certai fat oluble itam u h as v tam n A D E and K t de-lop t iti nal d f ie c es ch racter ed by ha g s in th sk n nd mp ment f f rt lity Th se defic nc es can b cur d by feeding m ll am t f l nole c d n un t ated f tty acid with two d ul le b nds Other un atu ated fatty d ch as l l n a id w th th ee doubl b nds d acl ido c with f r d uble bond e l ff t e S n th un atur ted f tty a ds nnot b ynth e i ed by the mal but mu t be ing ted i fat f m eg t ble u c they are k wn as th ent l f tty ac d

Transport of fatty acids Unde ert n ond tio f t e tran port d f om dep ts t th l e f for the metab lic rea t on They ar c rr ed i the blood stream h fly a t iglycerides but n dd tion may e t as f ee fatty id th c ll d

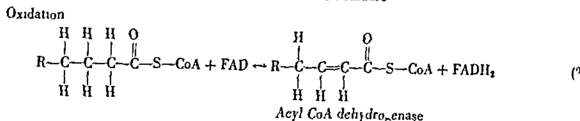
CURRENT CONCEPT OF FATTY ACID OXIDATION AND SYNTHESIS

Reaction — *Enzyme*

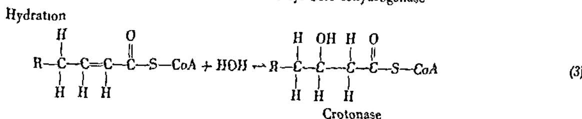
Activation



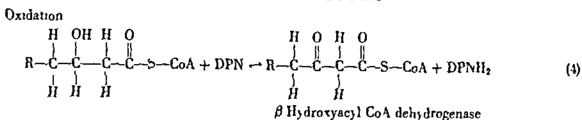
Oxidation



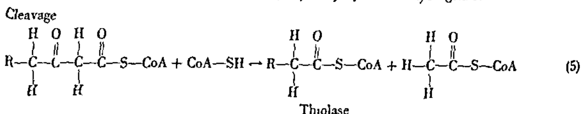
Hydration



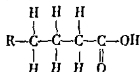
Oxidation



Cleavage



There are five reactions concerned in th oxida tion of higher fatty acids Each requires a special enzyme and two of the reactions require cofactors as oxidizing agents which accept the hydrogens from the fatty acids In reaction (1) activation the fatty acid is written as



in which only the terminal four carbon atoms are given R *represents a chain of carbon atoms up to* 14 in number The initial reaction con ists of acti vation by combination of the carl oxyl group of the fatty acid with coenzyme A yielding an acyl co enzyme A The enzyme is called the acti ating en zyme or thiokinase In reaction (2) fir t oxidation two hydrogens one each are removed from the α and β carbons with the *production of an un* aturated fatty acid analogous to crotonic acid *The enzyme* is called acyl CoA dehydrogenase and the cofactor which acts as the oxidizing agent is flavine adenine dinucleotide (FAD) In reaction (3) hydration hydrogen and the hydroxyl gr up (from water) are introduced at the α and β car bons respectively a β hydroxy acid i formed the enzyme is crotonase In rea tion (4) econd *oxidation two hydrogens are removed fr m the* α and β carbons of the β hydroxy a id to form a keto acid The oxidizing agent is dipho phopyridine nucleotide (DPN) In reacti n (5) cleavage acetyl CoA is split off Thus a fatty acid two carbons shorter than the original ne is formed Simultaneously the hortened fatty acid coml ines *with another molecule of CoA at the newly formed* carboxyl group to yield a new acti ated fatty acid The enzyme i β ketothi la e The new activated fatty acid undergoes the same erie of reaction and this proce s i repeated until the ntire fatty acid molecule has *been reduced mpletely to* acetyl CoA The fate of the acetyl CoA m l cules *will be discus ed l el w* *See* DIPHOSPHOPYRIDINE NUCLEOTIDE (DPN)

The interrelation of oxidati n or l reakdown of fatty acids and synthe is is hown in the *di gram*

condit n of maln tr tion is called cachexia See Lipid [w c.s]

Bibliog aphy F Lynen and S Ochoa Enzymes of f tty acid metabol m *B ochim et B ophys Acta*, 12 299-314, 1953 I H Page *Chemistry of Lipids as R lated to Atheroscle osis* 1958 W C. Stadie, *K t g e ts Di b tes* 7 1 3-180 1958 E.O Weim n, E. H Stri wer and I L. Chaikoff Convers n of fatty c ds to arbohydrate appli c n of sot pes to th s p oblem and role of Krebs cycl as synthetic p thway *Phys ol Revs* 37( ) 25 272, 1957 E. Werthe mer and B Shapiro The phys logy of ad pos tissue *Physiol Revs* 28 451-464, 1948

Lipostraca

An o de f the ub l ss Br n h opoda erected by D J Sc urfi ld fo the M ddl Devo an fo il *Lepidocaris hyni nsis* Thi o gan im was mall blind, and an nh b tant f fresh water It re em bled p ese t-d y a o tracan in some d ta l but differed in other d ta l f r exampl it had bi ramous antenn e trunk append ges lacked gills a d th first t pa were mod fied f r f edi g her a th remain ng appendages w re adapted f r swimm ng S B ANCHIOPODA [C B C]

B b iog aphy D J Scourf ld O a new type f cru ta an fr m the Old Red Sand tone (Rhyn e chert bed, Abe deen h re) *Phil T ans Roy S c Lond* Ser B 214 153-187 19_6

Liquefaction of gases

Liqu fied ga.es ar u ed n indu try in vari us mili ary pe ations nd in e t fi r ar h Al th gh th l rgest ut l zation f uch l qu d s by th teel chem al and r frige at on ndu tri s th mis l devel pm t prog ams have r c ntly acc u ted f r a i c e i gly ign fic nt hare of the ann l prod cti n Relat ly small am nt f the ri l quefied g r ed in c nt fi n est gat ns pr m ly f r t bli h g low t m pera u e i o ment in wh h tud e at temp a tu es bel w amb t may be c rr ed out S e CRYOGE IC ENGINEERING CRYOGENICS GAS

Sev ral p c es ha e b devel p d f r lique fy ng ga e Alth ugh gn fi a t d ffe en es n effi ency e tam g th m d ffi ulti c t red in ed cing th m re ffi nt t pr t c h m d them all ughly omp t t Co qu ntly t h e of th r fr ge at ng y l to b s d f liq f ct n f g n g s i mad la g ly th ba f o e en e I l ge ndu t i l l quefac ti n pl t howev gn fi nt ed t n i p o- d ct n t may b r l zed by use f th m e effi nt y le Th h s p d d an nti fo imp i g th t l ffi f th e y les w th the res lt th t h gh p ty pl nt des gn e n w u ally b ed p n th m st ffi i nt thermo- dy m p oces

Alth ugh ny th m dyn m p oce s wh h re- ult a l w g f th t mp rat uld i p pl b t l ed n th l quef ct on f som g ly f h f nd p a t l empl ym t

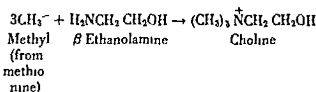
F g l P s u e- ol me (P V) diag am f a typ cal gas.

The e are n o d r of incr a ng c mple ity ap r compr i n u e of refrig rator to c ol the g at on tant p e sur u t l l qu fa t n c r ut liza ti n of th adiabat c pe form nce of w rk by the g s in cy l c proce s with r gene ati e c ling and u of the Joul Th m n pr ce s in a cycle with ege er t e cooli g Combi ations of these four proc s es ha e al ften been found eff cti e

Vapor compression In orde t l q efy any gas by mpress n ts t mperat re must be below its c iti al t mper t re a r qu m nt fr t rec gni d b Thoma Andrew (1863) The p oces of vapor mp es i n can be m st ea ly elucid t d with the h lp of the p essu e l me (P V) d agr m sh wn

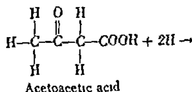
Fig l n wh h several typi l is therm are plotted The upper o e f r a tempe ature n exc s of the rit c l temp ratur T > T h w that a the gas is omp es ed the pre u e ri s mono- t nically with chang I ph e n m tter h w m h the g s i c mpr sed The T = T i otherm di ides th P V d gram such that t c tant tem p r tu e below T and at certa n defi ite pres- sure and lume f ea h is th rm (the locu f thes p nt l es n the dott d urve f r exampl point B) o further in e e in pre r with de c a ing l me b rved In t ad a l qu d ph e p og es ly f rm with d a i g lum until t p t C th yst m ll l quid Further de f the l me then leads t a sharply r ng I e of the p es r d to th mu h m lle com

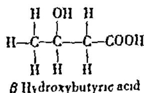
nonesterified fatty acids (NEFA) Fatty acids are also transported in the blood stream combined with phosphatides It is possible that the process of mobilization of fatty acids from depots may be under hormonal control A hormone *adipokinin* originating in the pituitary gland is stated to be this fat mobilizing hormone Under certain circumstances an excessive amount of fat is mobilized from the fat depots and transported for deposition *in the liver* Inadequate control of diabetes is one such circumstance The feeding of certain substances such as choline prevents this accumulation of fat in the liver Such a substance is called a lipotropic agent If the diet is deficient in choline the animal develops a fatty liver Methionine is also a lipotropic agent and when it is fed prevents the accumulation of fat in the liver It has been shown that methionine transfers its methyl group to *β ethanolamine to form choline The reaction is*

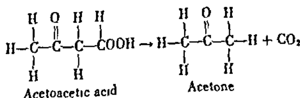


This process is called transmethylation

Degradation of fatty acids Liver muscles and other tissues can break down the fatty acid portions of fats to smaller molecules This process of oxidation is called β oxidation because the second or β carbon counting from the carboxyl group is oxidized As a result the fatty acid chain is shortened by two carbons forming acetyl CoA In the muscles and other organs acetyl CoA is further oxidized by the Krebs cycle as already described *but in the liver under certain circumstances all the acetyl CoA formed is not oxidized Instead* two molecules of acetyl CoA may form acetoacetic acid which cannot be further oxidized by the liver Acetoacetic acid is transformed into β hydroxybutyric acid or acetone according to the following reaction







These three compounds are called the ketone bodies They are formed only in the liver Under certain circumstances such as starvation or diabetes these acid derivatives of fat are formed in *excessive amounts in the liver and accumulating* in the blood give rise to a condition known as ketosis or ketoacidosis The excessive formation of ketone bodies leads to a high concentration of them in the blood a condition called ketonemia In addition exce s ketone bodies are excreted in the urine leading to ketonuria Such ketoacido is in the patient if allowed to continue unchecked results in his death Before the advent of insulin uch fatal acidosis in diabetics was quite common It is to be noted that the muscles are capable of oxidizing the ketone bodies and deriving the major portion if not all of their energy therefrom in starvation of diabetic ketosis However in the uncontrolled diabetic *subject the formation of ketone bodies may greatly* exceed the utilization of them by the mu cle or other tissues so that fatal ketosis results The excessive ketone formation in the diabetic is due primarily to an inability of the diabetic to synthesize fatty acids from carbohydrates or other sources This failure of lipid synthe is is believed to be basically due to the inability of the liver to metabolize carbohydrate in a normal way Oxidative formation of fatty acids to ketone body exceeds fatty acid synthesis ketosis therefore results

Uncontrolled ketosis in the diabetic patient brings about abnormal acidity of the blood de*hydration due to excessive loss of fluid* and lo of sodium In consequence the patient lapses into coma

Role of the phosphatides The pho phatides are compounds of phosphate and certain ba es containing nitrogen namely *ethanolamine serine and choline* the so called phosphatide la e When combined with fatty acids they tend to make the insoluble fatty acids soluble in water They al o tend to congregate at membrane surfaces and so are found in higher concentrations at the surface of cells They are not found combined with fat in the depot but can combine with the lipids of the blood and of the liver

Obesity The daily energy requirements of the body are met by the caloric yield of the fo d intake If more food is ingested than is required for energy demands the excess is con erted into fat and depo ited in the fat depots Long c ntinued inge tion of food beyond the caloric re uirements leads to the excess depo ition of fat or o e ity There are some physiologi t who elieve that obesity is due solely to overeating but others believe that certain indi iduals ha e a type of metal *lism which leads to fat depo ition e en wl en th* caloric intake is relati ely small

Cachexia In certain condition su h a hronic infectious di ea es cancerous or ther malignant growth dial etes hyperthyroidi m an ex e i e lo s of fat may occur leading t emaciati n and dimini l ed fat store f tl e body Su h an xtr me

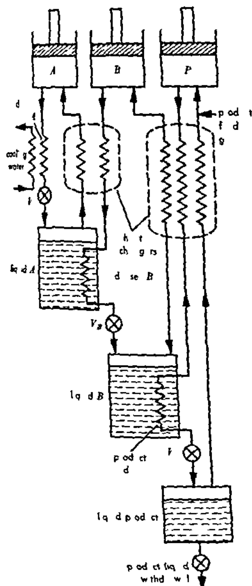


Fig 3 G lq f ct by d f p c m- p ss f g t

h th t ha g t d t occ tr p ally th t is, adi b t lly d ev r bly Th m a ik t th ch ng n qu st m t b r t d ut n ch a w y th t n l t h ge t ke pla e b t een the b t n nd its s und g d th internal f te d g t p od th h ng r t ll time b l n ed by e pc di g e ter l f es th t i th gh t th ha g the ystem em qu l b m l p a t h pr e ses b pp x m ted but t lly r l d Th i t p p oc m t oft n t l ed f g t d l q fi b l r cycled g is the eve bl f l t p f ga Th ad b t q me t m y b t fied r l t ly ly by t d d m thod f th rmal lat n well a b i g th p oc to oc ur s rap dl th t th ffi nt t m l ble f r tra f r f he t fr m r d g to th s b t e. A

re er il le expa ion f a gas from a high t a l w pre ure can be appr x mated with either a pi ton or turbine-typ expander The f rmer has l een the mo e w dely i ed the latter alil o igl tl e m re efficient handle i ch large vol mes of ga in proport on t t ze th t it devel pment and actual u e ha depended upon the need f r large producti n fac l tie for l quef ed ga es In addi tion w de pread u age of l oth type f expanders l as l en retarded until recently by la k of uital le meth d f lubri at on f r m ing parts and l ear ings at ery l w temperature I rd r t maint in the high the r t cal eff cien y inherent in th type of cycle h at generat on by fr ction i these ex pa der m i t l e minimized l ecau e all tempera ture incre e produced l y a g en am nt of he t r u ually appre iably larg r at l w temperatur s than at high

The mplest type of refrig r ting mach n em ploying th bo e principle i the gas ref g rator h wn n Fig 4 In an actu l mac) i e of the type sh wn expansi n f ai fr m 40 to 1 tm pre sure wh n th gas temperat r t the expa der int ke i 200 K r sults in n exit temperature f b ut 100 K In pr n ipl this refrigerat ng ma h e uld l s rve a a liq efier f r the w rk ng fl id If the xpander were ad quately i lat d t tem p ature wo ld fall progr s ely with co ti ed operati n and eve tu lly the gas w ild l qu fy in th e pand r it lf Such a proces highly in ffi ent howev l ec u e the liq id f rmed w t the wall f the cyl nder o tu bin This f l tate he t flow f m the hot cylind r wall to th w k g ul ta ce and introduces d l le i r r b l ty int the y le In add ti n the forma t n f l q d i the xp nder u ually nt odu e i s mechan al in tab l ty Hen e i p ctic th p nder a e u d o ly to p oduc the l w t mp atu e requ s t fo l quefact n The p o-

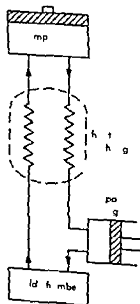


Fig 4 Sch m t c fl w d g m f g f g to

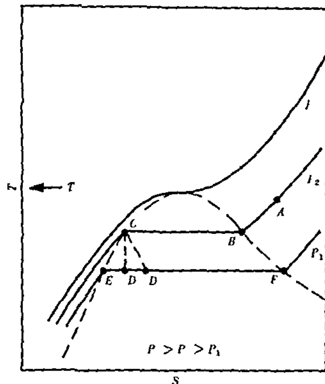


Fig 2 Temperature-entropy (T S) d agram fo a typical gas

pressibility of the liquid Assuming the critical temperature of a gas to lie above ambient liquefaction of a ga by vapor compression consists simply of compressing it *isothermally until it liquefies*

A procedure whereby a liquefied gas at a temperature below amlient can be produced using a vapor compression process is best de cribed with the help of a temperature entropy diagram for a gas *In Fig 2 the decrea e in entropy S with temperature T* for a gas held at con tant pressure is shown by the various curves labeled P_1 P and P (*see* ENTROPY) At some temperature less than T for every pressure le s than P (for example point B) liquid *will begin to form at con tant tempera* ture with further decrease in volume and continued withdrawal *of heat from the gas Let it now be* a sumed that the vapor has been entirely com pres ed to a liquid (path $A \rightarrow B \rightarrow C$ in Figure 2) *If at point C the confining pressure that is the* apor pre sure *on the compres ed liquid is in* exce s of atmospheric pressure the liquid can be isolated thermally from its surroundings and the confining pressure lowly reduced The liquid will *then boil but due to its thermal isolation the heat* of vaporization can be upplied only by the sen ible heat of the liquid it elf The whole liquid is there fore cooled at the expen e of vaporizing a part of it On the *T S diagram* Fig 2 this result is illustrated by the *path $C \rightarrow D$ as uming* the pressure reduction is carried out lowly and hence qua i reversibly For such an isentropic expan ion this *diagram* provide a direct determination of the re maining amount of liquid The fraction of gas produced is gi *en by the length ratio FD/FF* that for the liquid is *DF/EF* In practice the exp an ion *of the compre* ed liquid is carried out irrever ibly through a valve Under the e *conditions a larger* fraction of liquid is evaporated as hown by the path $C \rightarrow D$

When refrigeration is the objective of the proce s outlined above (which i frequently the ca e) the ga formed in the *throttling stage as well as that* originating from evaporation of the cold liquid is returned to the compres or intake and the cycle just described is repeated By balancing liquid evaporation due to heat leak with liquid production by *expansion teady conditions can be* achieved in the low temperature re ervoir Refrigerators of this type are useful in the liquefaction of still other gase *If the cold liquid produced i* withdrawn as product and u ed elsewhere a lique*faction rather than a refrigeration cycle i the re*sult Make up gas in an amount equivalent to that liquefied must then b continuously introduced to the cycle at the compres or intake

Refrigeration When the critical point of a gas *lies below ambient temperature a refrigerator* can always be u ed to cool the gas sufficiently to liquefy it by the vapor compression proce s de crib ed above Refrigerators are al o employed to prec ol the feed gas in other liquefaction cycle pr ducing *thereby a more nearly rever ible and hence more* efficient proce s Because not only different u e but also many types of refrigerators exi t the particular one chosen for any given application always requires a careful matching of proce s re*quirements to refrigerator characteri tic In thi* section therefore it will be possible only to ut line the basic aspects of gas liquefaction u ing refrigerators

In any refrigerating machine with gas tream flowing from high to low temperature region and conver ely it is neces ary to prevent the e circulating ga es from tran porting heat energy thu *introducing large and unde irable heat leak* into the cycle By using a device called a heat ex*changer heat energy can be tran ferred acro s the* medium eparating the gas stream in uch a way *that the warm tream is cooled* and the old tream warmed over es entially the same temperature in terval while ideally no heat energy flow along the *temperature gradient f the exchanger A simple* heat exchanger consi ts of two concentric copper tubes through which countercurrent gas streams flow with heat being tran ferred a r the copper surface adjacent to both streams

*A particularly imple refrigerator i a c ntinu*ously repleni hed l ath of a liquefied ga boiling under reduced pre ure and hence at a lower temperature than ambient a de crib ed in the previ u section By using e eral of the e bath ea h l il ing at a lower temperature and each acting *in turn* as a conden er for the one with the next l w t boiling point a ca cade type liquef er may l e a embled a illu trated in Fig 3 S e REFRIGERATION

Performance of external work Tl maximum p ible cooling effect re ultant fr m any spontaneous change in the state of a sul tance obtai

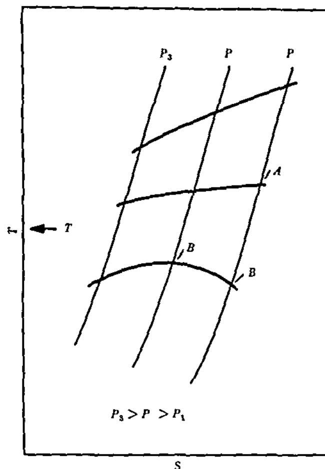
rev r ble e pan io of a ga from a high to a low p e sure c n l e approximated with either a pi t n or turbine type expander The former ha been the mo widely u ed the latter altho igh th more efficient handle such large volumes of ga in p oporti n t its ize that its de elopment and actu l u l a depended upon the need f r large pr duct on facilities for l quefied ga e In addi ti n w de p ead u age of both types f expanders has bee retarded until re e tly by lack of su table m thod of lub icati n for movi g part and bear ng at ery low temp ratu es In rd r t maintain the high theoretical efficiency inh rent i thi type f ycle heat g ne ati n by fr ction in the e ex pande s must be min mized becau e all t mpera tur nc e e pr duced by a gi en amou t f heat are u u lly appreciably l rger at low temperatu es than at high

Th implest type f refrigerating ma h ne em pl y ng the ab ve pr nciples i the gas r fr gerat r sh wn in Fig 4 In a actu al mach ne f the typ hown expan on f air from 40 to 1 atm pre re when the ga temperatu e at the expander ntake s 200 K esults in an e it temper ture f ab ut 100 K In p cipl th s ref g ti g mach ne c ld lso rve s a l qu fer f th w k ng fl id If th xpander we dequately n ulated it tem p tu e w uld fall progres i ly w th continued op r t o nd ev ntually the ga w uld liqu fy in the xp nde t elf S ch a p oces i h ghly in effi nt h wev r becau e tl l q d s f rmed wets the walls of the yl nde o t rb ne This fa il tates he t flow from the h t cyli der wall to th w rk ng ub ta ce d nt oduces c ns de ble i e r b lity i t th cy le In add tion the form t on of l qu d th e pa d u ally ntroduce er u mecha cal in t bil ty He e, n pra tice the exp nd r a e ed only t p du e the l w temperatures requi t for liqu fa tion The pro-

Fig 3 G l q f ct by d f vap -c m- p ion f g t rs

wh n th t cha g s au ed t oc ur i ntr p ally th t ad b t lly a d ev ibly Th s mea th t the h ge n q st n mu t b arri d ut n su h a way that n h t x ha g t ke pl b twee th b t e d t irr d ng nd the int rnal f t d ng t p d e the l ang t ll t mes bal n d by p d g t rn l f tees th t thr ugh ut th h g th yst m r m i n q l b m In p a t u h p e e an be app m ted b t n r a tu lly e l d The i nt p pr m t ften ut l ed n e fr g r t d lti fi b f ycl d gn t the bl ad b t p i n f g Th ad t t eq m nt m y b t fied l t ly ly by nd d method f th rmal n l ti w ll s by a g th p s t ce r so ap dly th t th e uffi t t m l bl f t a f f h t f m rrou d g t the b t n e. A

Fig 4 S hem t flow d g m of g f ig t



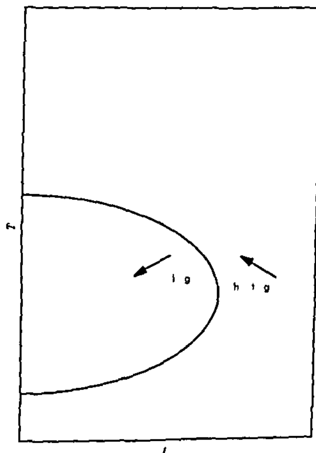
F g 5 Temperatu e ent opy d ag am for a gas (h gh tempe ature region)

duction of the actual liquid is always carried out either by vapor compression or the Joule Thomson process Discussion of the latter is reserved until after the next section but an application of the principles developed so far is illustrated by the A D Little hydrogen liquefier In this compact device the working substance helium gas circulates through two reciprocating expansion engines operating at two different temperature levels The exit temperature from the lower temperature engine is maintained at approximately the boiling point of hydrogen The hydrogen gas to be liquefied is cooled by passing it through a heat exchanger counter to the expanded cold helium until its temperature is reduced sufficiently to permit liquefaction by vapor compression

Joule Thomson expansion Under certain conditions an irreversible adiabatic expansion of a gas (or a liquid) through a throttling device such as a valve can result in a decrease in temperature of the effluent gas A thermodynamic analysis shows that in this process called a Joule Thomson expansion the heat content or enthalpy of the gas is unchanged If the temperature at which the expansion is carried out is above a particular temperature for each gas the gas effluent from the throttle valve will be warmer than that at the valve inlet below this temperature called the inversion temperature expansion will result in a cooling of the gas In order to use this cooling effect in gas liquefaction the expansion temperature must always be below the inversion temperature The list shows the inversion temperatures of a number of common gases

Gas	T_i K
Helium	51
Hydrogen	205
Neon	242
Nitrogen	621
Argon	723
Oxygen	893

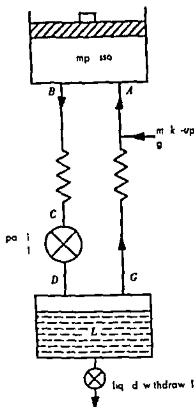
from which it will be noted that neon the hydrogen isotopes and the helium i otopes are the only gases not below their inversion points at ordinary temperatures Precooling before expansion is nece sary only with the e three gases in order to obtain refrigeration from the Joule Thom on process In Fig 5 a simplified T S plot of a typical gas is presented On it is shown the variation of S with T for three different pressures The heavy lines represent constant enthalpy lines and hence display the temperature history (as well as the entropy history) of a gas in an i enthalpic expan ion *Above the point marked T_i it is seen that a Joule-*Thom on expansion always results in a temperature rise no matter what the initial pressure At T_i and here only for very low pressures for example point A there is no change in T upon expansion Below T_i there is a drop in the temperature upon expansion first at very low pres ures and then with further decrease of the temperature at increasing pressures (path $B \rightarrow B$) At low tem



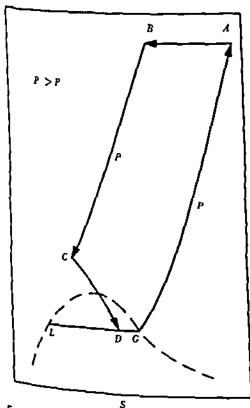
F g 6 Invers on tempe ature e sus p e sur fo a gas

peratures, the p es ure at wh ch c ol ng occurs po pan gain decrea e. If the e tempera tures at hich the inversi n occur are plotted against the p e ure o ghly p rab lic curve s h h n n Fi 6 is obta ned Expan ion from any p int withi the pa abola always produces cooling From a point outs de a heating occurs in ti lly u til the press re and temperature f the ga is redu ed uffic ently to bring it with n th parabola.

In considering this process for g s l q efacti n it must be m ti ned that at lea t until the expa sio m de t occ r t ery low tempe atures the Joul Thomson process is a f r le s effecti e cool ing process than i entropic expan on By cycling the gas cce ely thr ugh a compres or heat exchang and an e pan i n al howe er the cooling btained f om the pa ag of each ma s f g thr gh th alve can be m de umulat e In th a the t mp t re f the exp n on val e s continu ly ed ced unt l finally eno gh refrigerati n p oduced to liquefy a fracti n f the m ng ga. B epa t g th liquid and returning th emaind to the compre s r thro gh the he t exchange th te f cool ng of the expan on alve begins t dec and e entu lly a teady st t re hed at which the refrig ration emoved as liquid j t balances th t prod ced in the expan si n. In Fg 7 th s steady tate is represe ted on TS diagram. The atio DG/LG is the fraction of



Fg 8 The L d g s l q f ct cy le



Fg 7 J le-Th mso l q f ct cy l f m pe ature-e ropy diag m (h gh t mp t d two-phase reg)

liquid pr duced per m le f gas pas ng through the Joule-Thom n alv the fr ction DL/LG repre ents moles f gas ret rn ng to the compre so at wh ch po t make up ga is added to the ystem an amount neces ary to maintain steady st te ond tions th o gh ut the cycle The g e t att act n of the J ule Th ms n proc s is its lack f m vi g p rts at l w temperatures Fu thermore it pr d a sat factory method f p duci g the l q id and sepa ting it f om the gas stream as co tra ted with th p iously ment o ed d fficul ties e ou t r d when th l q id i allow d to f rm in a tu b ne r e pan ion ng e

The J ule-Th ms n p e is ed in many d ff nt way in the pract ce of gas l quefacti n Th mplest s that fi t de eloped by C rl von Linde sh wn in F g 8 The l tters attached t the draw g orr pond to th tate of the g as h wn n F g 7 In pract e g pu fi r m t be introd c d d wnst eam of th comp e s in rder to pr nt nd n ibl imp rities f m cl gg g th he t e hang r Th bas cycle h been ad pted in ma y way of wh ch few (1) use of an expan n gine po c mp s on or a gas f ig at t p ool th g f ed t th Joule-Thom n al e (2) u f indep nd t h gh nd low p e e c c its with w thout additional p ec l g and (3) use of cl ed r u t r f g a ti n w th l q efact n by h t ha ge with th w k ng ub t n It ho ld lso be n ted th t the reve s bl p n n of the l qu d thr gh th ottl l me t o ed n th ct n n ap

compression is an isenthalpic or Joule Thomson expan ion

In the discussion of the four basic methods of gas liquefaction given above no association of a particular gas with one or more liquefaction schemes has been made This omission has been deliberate because with few exceptions all schemes will work with all gases and therefore as mentioned earlier the choice of method is governed by other considerations

Storage of liquefied gases Liquefied gases at temperatures below ambient could be stored in definitely if it were possible to prevent heat influx to the liquid from the warmer surroundings No perfect heat insulators exist however hence heat constantly flows at a rate dependent upon the quality of the insulation into all such liquefied gas reservoirs If the container is vented to the atmos phere this heat leak causes continuous evaporation of the reservoir contents If the container is sealed the heat leak will cause the temperature of the liquid to rise with concomitant increase in the pre sure until either the temperatures of the liq uid and surroundings have equalized or until the increased pressure has ruptured the container Because sufficiently effective insulation is now available to reduce boil off losses to economically tolerable levels atmospheric venting is common practice in most large storage facilities Occasion ally however because of hazard value of the prod uct or liquefaction costs no loss storage of lique fied gases is required This may be accomplished for short periods of time by simply plugging the vent line and allowing the temperature of (and pressure in) the reservoir to rise For longer pe riod refrigeration at the temperature level of the liquefied gas must be supplied to balance the heat leak to the container

Liquefied gas containers range in size from tiny glass laboratory dewars for specialized studies with small amounts of rare liquids to reservoirs con taining hundreds of thousands of gallons for use in industry The insulation employed depends en tirely upon the proposed usage In a mi sile tank for example the storage time is short insulation can therefore be almost eliminated especially be cause minimization of propellant tank weight is a prime con ideration For storage of liquid helium however where reliquefaction is costly and the gas supply itself is not unlimited use of the best insula tion available is usually justified See ATMOSPHERIC GASES PRODUCTION OF [E F H]

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Liquefied petroleum gas (LPG)

A mixture of petroleum ga es principally propane and butane which must be stored under pressure to keep it in a liquid state At atmospheric pressure and above freezing temperature these sub tances would be gases Large quantities of propane and butane are now available from the gas and petro leum industries These are often employed as fuel for tractors trucks and buses and mainly as a do mestic fuel in remote areas Becau e of the low boil ing point (−44 to 0 C) and high vapor pressure of these ga es their handling as liquids in pressure cylinders is necessary Owing to demand from in dustry for butane derivatives LPG sold as fuel is made up largely of propane On a gallonage basis production of LPG in the United States exceeds that of kerosine and approaches that of diesel fuel

Operating figures for ga oline die el and LPG fuels show that LPG compares favorably in co t per mile LPG has a high octane rating making it useful in engines having compression ratios above 10 1

Another factor of importance in internal com bustion engines is that LPG leaves little or no en gine deposit in the cylinders when it burns Also since it enters the engine as a vapor it cannot wash down the cylinder walls remove lubricant and in crease cylinder wall piston and piston ring wear Nor does it cause crankcase dilution All these fac tors reduce engine wear increase engine life and keep maintenance costs low However allowances must be made for the extra cost of LPG handling equipment The LPG must be stored in relatively heavy pressurized tanks and special equipment must be used to fill the fuel tanks on the vehicles See GAS TURBINE INTERNAL COMBUSTION ENGINE PETROLEUM PRODUCTS [M SO]

Liquid

A fluid which flows under exceedingly low shear stresses and which conforms to the shape of a con taining vessel but which lacks the capacity to ex pand indefinitely Above their critical tempera ture liquids are indi tinguishable from den e gases and it is possible to devise an infinite num ber of paths by which the transition from a liquid to a gas may occur continuously Ordinarily the range of pressure and temperature over which the liquid state exists is intermediate between that for solids and gases For substances wh e triple points lie above 1 atm pressure however the liquid state is stable only at higher pressures

Structure of liquids For normal sub tance the liquid is formed from the solid at the melting point by the absorption of the latent heat of fu i n Gen erally the density of the liquid state i slightly lower than that of the solid and melting i accom panied by an increase in volume A relati ely small number of substances in luding i e bi muth gal lium germanium and silicon c ntract on melting No sati factory explanation of the pr ce of melt ing exists largely becau e of the inadequacy f the theory of liquid Liquid like soli po e a vapor pressure which depend up n the temp era ture (see VAPOR PRE SURE) and b il when the vapor pre ure is equal to the aml ient pre ure The energy al orbed in the liquid vap r pha

change of one mole of liquid is called the molar latent heat of vaporization and the value in calories approximately equal to 21 times the absolute temperature of the normal boiling point (Trouton Rule). In the gaseous state there is complete randomness in the spatial positions of molecules relative to one another and to a good approximation at low vapor densities there is a negligible intermolecular potential energy. By comparison, the atoms, ions or molecules in the crystalline state occupy definite positions on a three-dimensional lattice and approach perfect order in the details of their arrangement in space. Except for the relatively small kinetic energy of vibration of atoms about their equilibrium positions the energy of the solid state is entirely potential. The mathematical theory of both the gaseous and solid states is well developed because of the mathematical simplicity resulting from complete randomness on the one hand and complete order on the other. Liquids occupy positions intermediate between gases and solids and lack either the utter molecular chaos of gases or the ideal structural regularity of crystals. Molecules in the liquid state experience strong forces of attraction and repulsion but have nevertheless sufficient thermal kinetic energy to move about more or less independently of one another. As a result, the theory of the liquid state must necessarily be very complex and no generally rigorous theory exists.

The mathematical difficulties of an exact theory of liquids are prodigious although much has already been accomplished by the efforts of Max Born, H. S. Green, J. E. Mayer and John G. Kirkwood. Approximate theories have been constructed from the one of two points of view (1) a model which represents the liquid as a dense gas and which attempts to calculate the thermodynamic data properties of the liquid from the pairwise interaction of molecules and (2) a model which treats the liquid state as an approximation to the crystalline state in which a certain degree of configurational disorder has been introduced.

Studies of the structure of liquid metals, fused salts, liquid gases and a number of organic liquids by X-ray diffraction have shown that quite a bit of order is present at short distances in liquids. This short range order is very similar to the regularity observed in crystals but extends only over a few atomic or molecular distances. The long range order characteristic of the crystalline state is completely missing. Diffraction patterns obtained from liquids reveal a few maxima and minima, and the analysis of these patterns determines the probability that a second atom will be found at a given distance from a central atom. It is then possible to calculate the average number of nearest neighbors to a given atom in the liquid and the mean number of nearest neighbors of a given atom in the liquid, and the latter is smaller than the number of the liquid which ... [illegible]

sult is that of a time-blurred imperfect approximation to a crystal.

Liquids vary considerably in the nature and strength of the forces responsible for cohesion. In molten salts which are excellent conductors of electricity and are completely dissociated into ions the forces are predominately coulombic. Liquid metals which are also excellent conductors consist of positive metal ions and electrons which are quite free to move in an electric field. The condensed rare gases as well as liquid nitrogen, oxygen and hydrogen and nonpolar organic liquids owe their cohesion to van der Waals forces (see GASES). These forces are comparatively weak and of short range and the boiling points of such liquids are accordingly low. Dipole-dipole forces are responsible for much of the cohesion in polar liquids. In water, hydrogen fluoride and organic liquids containing molecules with hydroxyl groups hydrogen bonding is responsible for relatively high boiling points and low vapor pressures. See MOLECULAR ASSOCIATION.

Properties of liquids. The inability of liquids to withstand shearing stresses under their viscous flow properties. Viscosity varies widely among liquids and diminishes exponentially with temperature in all cases in which structural changes are not occurring. One of the most interesting of all liquids is liquid helium produced by Joule-Thomson expansion of helium gas which has been cooled below its inversion temperature. Liquid helium boils at 4.19 K and is a normal liquid having, however, an unusually large zero-point energy. When further cooled it undergoes a remarkable change into helium II at 2.19 K. The latter is a quantum fluid possessing exceptionally low viscosity (about 1/1,000,000 of that of water). It appears to possess about the same degree of order as solid helium and is therefore of great interest for the theory of liquids. *See* BOILING POINT; EQUILIBRIUM PHASE; LIQUEFACTION OF GASES; MELTING POINT; SOLUTION; SUPERFLUIDITY; SURFACE TENSION; VISCOSITY OF LIQUIDS. [N.H.N.]

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Lissajous figures

Plane curves traced by a point which executes two independent harmonic motions in perpendicular directions, the frequencies of the motions being in the ratio of two integers (see HARMONIC MOTION). Such figures produced on the screen of a cathode-ray tube are widely used in frequency and phase measurement.

Methods of constructing. Mechanical, optical and electronic methods may be used to construct Lissajous figures. Blackburn's pendulum consists of one dense pendulum hung from another with the two axes of rotation at right angles. The Lissajous figure is traced by the bob. An example of an optical method is afforded by a beam of light reflected successively from two small mirrors each

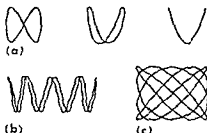


Fig. 1. Typical Lissajous figures for ratios of vertical frequency to horizontal frequency of (a) 2:1 with various phase relations, (b) 8:1, (c) 5:4. (From F. E. Terman, Radio Engineers' Handbook, McGraw-Hill, 1943)

mounted on the prong of a separate tuning fork; the forks vibrate in perpendicular directions, and the image of the light source, focused on a screen, traces out the figure.

The cathode-ray oscilloscope furnishes the most important and practical means for the generation of the figures. The x deflection plates of the tube are supplied with one alternating voltage and the y deflection plates with another. If the frequencies are incommensurable, the figure is not a closed curve and, except for very low frequencies, will appear as a patch of light because of the persistence of the screen. On the other hand, if the frequencies are commensurable, the figure is closed and strictly periodic; it is a true Lissajous figure, stationary on the screen and, if the persistence is sufficient, visible continuously as a complete pattern. See OSCILLOSCOPE, CATHODE-RAY.

Frequency measurements. Measurement of frequency in sinusoidal wave motion (for example, in alternating electric current) may be accomplished with an oscilloscope if one of the alternating voltages is derived from a variable-frequency calibrated oscillator. The standard is adjusted until a stationary figure results. If f_v is the frequency of the signal on the vertical deflection plates and f_h that on the horizontal plates, then f_v/f_h equals the number of times a side of the figure is tangent to a vertical line divided by the number of times the top or bottom is tangent to a horizontal line. The shape of the figure depends also on the relative phase of the signals (see Fig. 1), and in the case where one half of the figure coincides with the other, the rule just stated does not hold. This situation is not troublesome in practice because unavoidable slow frequency drifts of the signals prevent the figure from being exactly stationary; instead, the shape of the figure changes as though the relative phase of the signals were slowly changing.

In some cases the standard is of fixed frequency and the unknown is nearly equal to the standard (or to some multiple or submultiple thereof). The figure will drift slowly through the various aspects it can assume for the nominal ratio involved. The actual ratio can be obtained from the nominal ratio and a correction determined by the rate and direction of drift of the figure. This method is particularly valuable for the intercomparison of standards.

Phase measurements. These usually involve two signals of the same frequency. In this case the Lissajous figure is an ellipse of which the shape and orientation depend on the relative phase and relative amplitudes of the signals, as shown in Fig. 2. The relative phase θ is given by

$$\sin \theta = \pm B/A$$

in which A is the maximum half height and B is the intercept on the y axis. Figure 2 shows how the quadrant in which θ lies is determined by the orientation of the major axis of the ellipse and the direction of motion of the spot. If the latter is unknown, the resulting ambiguity amounts to that in the sign of $\sin \theta$ once it is decided which signal is the reference. The ambiguity can be resolved by shifting the phase of either signal in a known direction and noting whether the phase shift indicated by the figure increases or decreases.

The most precise comparison can be made when the ellipse degenerates into a straight line. This condition is therefore used as a null in measurements made with a calibrated phase shifter. The

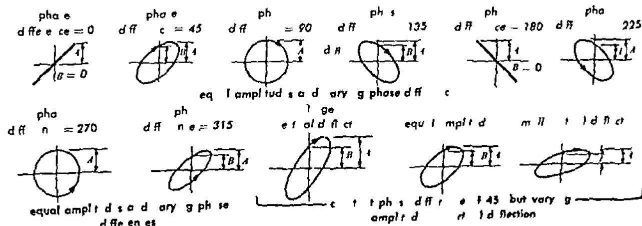


Fig. 2. Typical Lissajous figures of 1:1 frequency ratio. (From F. E. Terman, Radio Engineers' Handbook, McGraw-Hill, 1943)

mknown ph se h ft d tu bs th ll d the cal brated pha-e h ft resto es it

More compl ated figu es a e employed in th calib t of pha e hifters A ignal at the de ed frequen i c ected th ough the ph shft r t the y pl tes f an oscilloscop a d 'so, thro gh a f equency m lt plie to the x plates If the f que cy multipl t on is 8 for e ampl th Li ajo s fig e will appe as i F g 13 The phase hifter i then uc es ely set t th n po t for which one-h lf of the fig re co ides with the other these p tions w ll correspond t pha d ffe ence f in th ca e ~/8 ᑕ PHASE ANGLE MEASUREMENT [M CR]

Bibl g phy Lord R yleigh *Theory of Sound* vol 1, reprint, 194 F E Term and J M P t m, *El ct onic Me ur m ts* 2d d 1952

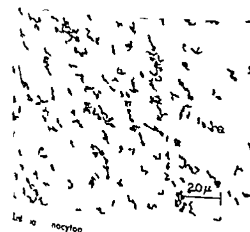
Listeriosis

A disease f man d animal au ed by a mall gram-positi e ba ill *Listeria mon cytogenes* Th mi roo gani m, membe of the family Cory nebacteriace e h been olated from man d 27 spec es of a im ls and birds i 30 cou tries from th Arcti to the Tr pi s The ep dem logy is n t understood

The o gani m m sur s 0 5 by 1–3 μ Small rod with ro nd d end predomi at showi g palisad form u n and short cha s Y ung b oth cult es di lay char cteri tic tumbl g m t lity G wth n ampl medi is e h n ed by e ri hme t w th blood or gl c e. There re f ur se otypes (se IMMUNOLOGY)

Listeriosis i animal t kes many forms uch s meningoencephalit in wine goats and sheep distemp like d a e in d gs a d fo es ge eral ized infection in rabb t and gu e p gs with fo l liver necro d ma ked m ocyt si Abortio with ext n i f t l nec o i may occ i rum nan su h as cattl

List ri in man occu s prima ily a m ni git or gra ul m t inf nti ept c with h gh f t l newborn m rtal ty and n ros Septic m l co m n (SEPTICEMIA)



Lis io nocytog

Diagnosi depends on i lati n of *Listeri* from appropriate clinical pec men Ide tification i certain if a pure cult re in tilled i to the rabb t c n juncti a produces e e e keratoc juncti itis An aggl ti at on titer of er 1⁄400 n patients erum i diagnostically signifi ant

Treatm nt hould be based on in vitro a tibi ti se siti ity te ts on the train isolated *Se* BACTERIOLOGY MEDICAL CORYNEBACTERIACEAE EPIDEMIOLOGY [R W R]

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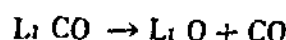
Lithium

With n atom number of 3 a d an at mic weight of 6 94 l thium Li stand t th head f the alkal metal family i group Ia in the periodic table of th eleme ts Lith m in nature i a mixture of the two i otopes Li a d Li Much of the commer cially proces ed l th um in the U ited State has been subjected t isotope sepa tion in the nterest of obta ni g the p re lighter ot pe of lithium Li The l ght l thi m is t pe plays n important ole n therm ucl pr ces es Lith m a ail ble in the m ket may thu ha e a n d ably differ ent at m c weight becau of the remo al f the l ght i t pe It i th l ghtest ol d el m nt, a d a ft l w melti g r ct e metal In ma y f its physi l a d h mi l p p rti it resembles the alk l e-ea th met l i gr p IIa a m ch as, m e than t d es th alkal m tal fam ly f whi h it a membe

The lem nt wa fir t d co e ed b J A A f ed n Swed n dur g ct a lys of p t lite Th m tal wa first lated by S H mphry D vy i 1818 by elect olysi

Uses The maj r d str al s of l th um in the f rm f l th m te at as a th ck ner f lu b cat ng gr e Lithi m ba gr s c mbin h gh w t r st n w th h gh temper tur e t c a d g d low temp atur p ope tie The all p po e grea es epl e a m lt t de of pec alized gr s s nd th y ha e capt red ab ut e-th d f th tot l t m t g e ma ket A th imp rt t e f l thi m c mp ds i e m pec fi lly i p l n m l for m lat The maj ct of the l th um s

flux In ceramic mixtures lithium carbonate read ily undergoes the reaction



$$Li\ CO \rightarrow Li\ O + CO$$

yielding the Li O as one constituent of the oxide mixtures of which most ceramics are compo ed Alternatively lithium aluminum silicate ores can be used directly

There are a number of les er u es for lithium and its compounds Lithium hydroxide is u ed as an additive to give longer life and higher output in the alkaline torage batteries known as Edi on cell Lithium chloride and fluoride are u ed in welding and brazing fluxes lithium copper and lithium silver alloys are u ed as elf fluxing brazing alloys Lithium perchlorate has been uggested a an oxidizer for solid propellant rocket mixture it offer a higher percentage of available oxygen than any other perchlorate due to the low atomic wei ht of the lithium

Occurrence Lithium i a moderately abundant element and is present in the earth s crust to the extent of 65 parts per million (ppm) This places lithium a little below nickel copper and tungsten and a little above cerium and tin in abundance In ea water there i about 0 1 ppm of lithium It i found in human and animal organi ms in oil in mineral water and in plants uch as ocoa to bacco and eaweed Its pre ence in the sun s at mo phere has been e tal lished

Although lithium occurs widely in nature the concentrations in ores are generally quite low un like odium and pota sium who e relativel pure halides may be mined or pumped from brine well Lithium re embles rubidium and cesium in it manner of oc urrence a part of complex ilicate mineral Lithium ore as ay are u ually expre ed in term of per cent of lithium oxide Li O and 1 0% of Li O afford a commercially proce al le ore Mo t commer ial ores run from 1–3% Li O virgin ore rarely contain a much as 6% In North America the m t common lithium ore i podumene which generally occur in pegmatite formati n in a ociati n with feld par The large t known re erve are in the King Mountain area of North Carolina in Quebec and in Manitol a Sub stantial quantitie of lepidolite and petalite occur in Africa particularly in Rhode ia Amblygonite the other c mmercially important lithium mineral i found in Europe Africa and South America A nonmineral ource of lithium i the brine in Searle Lake California Table 1 li ts the important lith ium ore

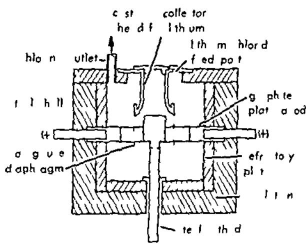
Table 1 Commercially Import nt lithium minerals

M l	Simpl fed f m l	% L O theo t l
Spo l	I AlS O₄	8 03
Lep l l t	I KAl F S O	4 09
P t l t	LiAlS O	4 89
Aml lygo it	LiAlF PO	10 10

Metallurgical extraction Lithium ore are c n centrated from 1–3% Li O to 4–6% Li O by heavy media eparation u ing den e nonaqueou liquid and by froth flotation The ilicate ore which are tho e proce ed mo t widely are then chemically cleaved by acid or alkaline proce e

In the acid proce podumene ore is fir t heated in a kiln to al out 1000–1100 C to change the natu rally occurring alpha podumene to l eta du mene a more friable le s den e crys tal form whi h is readily attacked by the acid The ore i then roa ted in a econd kiln with in exce of ulfuri acid Water leaching of the kiln product yield lithium sulfate which i treated with odium car l onate to give lithium carl onate The carl nate i converted to the chloride l y reaction with hydr chloric acid

In the alkaline proce podumene or lepid lite ores are ground and calcined with ab ut 3 part limestone to 1 part lithium ore at 900–1000 C Wa ter leaching of the kiln product yield lithium hy droxide which is converted to the chloride l y reac tion with hydrochloric acid



Cros s ct on of l th m cell

Dry lithium chl rid i tl e feed material f r the manufacture f lithium metal l y electr ly i The ell l ath i a tuall a m lten mixti re f lithium chl ride and p ta ium hl ride The ell i er ated at 100 470 C with a v ltage a r the cell of 8 9 It The current con umpti n in le trol i is al out 18 kilowatt h ur per p nd f lithium pr du e l Th illu trati n l w a t pi al lithium cell

Thermochemical pr ce es for tl e manufa t ire of lithium ha e l een tu lied l t t l a e n t l n ap plied c mm rcially

Physical properties The phy ical pr pertie f lithium metal wl ich make it attra ti e f r many f it pre ent and potential u are summarized in Tal le 2 (The value cite l ar tl e l t a ailal le there are many valu e in tl literature whi l li agree with tl em)

Noteworthy am ng th phy ical pr perti tl e high pecific h at (heat apa ity) large t m perature rang of the liq iid pl a e high tl rmal

Tab 2. Physic l propert f l thi m met l

Prop rt	Tempe at e		M t ic (sc ntific) u it	B t l (en ee i g) n ts
	C	F		
Den ty	0	68	0 534 g/cm	33 lb/ft
	400		0 490 g/	30 6 lb /ft
	800	14	0 4 g/ m	8 6 lb ft
M lt ng p t	1 9	3 4		
Boiling point	131	103		
Heat f f	1 9	3 4	103 l/g	186 Bt /lb
Heat of apo zat	131	103	4680 c l/g	84 0 Bt /lb
Visc s ty	00	39	5 6 m ll po ses	11 1 k t t
	400		4 0 m ll po ses	8 k t c t
	600	111	3 17 mill po ses	6 ki ti u t
V po pressure			0 8 mm	0 01 lb /
	10		91 0 mm	1 (lb / n
Therm l co d t ity	16	4 0	0 109 c l/(sec)(cm)(m)(C)	6 5 Bt /(l)(ft)(F)
	539	100	0 0 3 al/(sec)(cm)(m)(C)	1 6 Btu/(l)(ft)(F)
Heat capac ty	100	1	0 90 cal/(g)(C)	0 90 Bt /(lb)(F)
	300	57	1 0 l/(g)(C)	1 0 Bt /(lb)(F)
	800	14	0 99 l (g)(C)	0 99 Bt /(lb)(F)
Elect cal res t ty	0	3	1 34 m rol m-cm	
	100	1	t m rol m-cm	
Surf ce te n	00–500	39 93	Abo t 400 dynes/ n	

d t t l w c ts a d y l w de ty Lith um m t l sol ble n l q d n m a a d is l ghtl soluble in th l w r liph t c mi es b s eth l m It n ol ble in hyd oc l There a p bl hed d ta n the lub l ty of lith m met l i m lt n in g n lt

Chemical properties Lith m u d g es la e numbe of ct o th b th o ganic a d nor g nic re g ts

Ino ga c t ns L thi m rea ts w th xygen to form the m n xide Li_2O d the per x d Li_2O_2 The pe d LiO_2 i n t known nd may t ex t bee use f insuffi e t o m fo tw g n tom arou d the m ll l th um at m Lithi m i the nly lk l m t l that rea t w th n trog t oom temp tu e t fo m a it d Li_3N wh h s black

Lithium cts adily w th hydr g n at ab ut 500 C t f rm l th m *hyd ide LiH* Of ll the alka m tals, l th m act mo t r ad ly w th hy dr gen, nd i the nly lk li met l form ng h dride t bl e gh t be m lted witho t de compo i n An mportant r act n of LiH that th b fl id diethylethe at $BF_3(C_2H_5)_2O$ to y ld d bo an B_2H_6, r l th m b r hyd id $LiBH_4$

Th re t n of l th m m t l w th wate i ceed gl g r L th u re t d tly w th carbo to f rm th ca b de L C_2 L thium om b nes r dily ith the h loge t l at d tem per t es, f rm hal de w th the em f l ght. Lith m doe t bu n chl n nl b m p mably b u e f the f m t n f r sist b l de t gs

W h m l th m r ct t form th m d $LiNH_2$ Th t n m y b rried ut by h t g L h m t m f mm a at 400 C. o b t n th l qu d mm i n th p e f taly t ch s i n On h ting the am de l es amm ia t form th imide L NH l thi m i th nl alk li met l which f rm an m de

Lith um and carl n mo ide re t t giv l th ium arbonyl L CO rather un t bl pr du t

O g ni e ct o s Whil lithium d n t r t with p aff n hyd b n t d es und rg add t n e tion w th a yl ted alkene a d with d e Th add ti n of l thium t d en sy tem i the b i for the t l ti p l me at n of d e es t ynthet el tom ha ing atur l r bb r prop e t es O e rec ntl d el ped y thet c r bb m pl y l th m m tal d pe ed i pet ole m jelly th at l t t polym p ene t s p ly o- p e th ex ct tr t r l u terpart f n tur l he a r bb f om *H a b asil e s* (rubbe tre) L th m al o rea ts w th ety l nic m p u d r pl ng th a etylen hyd g n t m a d f rm g lith um cety l de wh ch a e m jor t ti th synth i f v t m n A

Lithi m metal e ct w th alc h l f m ng l th um alk de LiOR nd l berat ng hyd g n Alk x d f m les e dily w th l thi m th n they d w th d m a d the mm ci l til ty i m h le tha that of th sod m lk x des

L th m dd t rb y l mpo nd u h aldehyde a d ket n g i g l thium add tion mp nd a nte med ate whi h an be hydro- lyze l to n l h l Simil ly ga l th m m p d add t ld hydes d k tone g ing dd ti n p odu t whi h y eld alcoh ls upon hydrolysis O ga l thi m mpo nd eact with o g n c eid t gi add t o pr d ts wh ch an be hyd olyzed t ket e thi t n u ed n ne step of th t m A y th

Lithi m n al be sed n ju ct o with m m i r am nes t eff t niq red ct of ar g c mp nds f e ample the re d t f omat hyd a b t m ool fin

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Bibliography R N Lyon *Liquid Metals Hand book* 2d ed Navexos P 733 1954

Lithosphere

A term initially used in a general way to distin guish the rock pha e of the earth from the hydro sphere biosphere and atmo phere at the surface of the earth The term litho phere has been u ed variously in recent geological literature to desig nate the crust ("upper litho phere) the cru t plus the mantle (that i the total sili ate pha e of the earth) or the entire solid part of the earth (crust + mantle + core) The c re i thought to con ist mainly of a mixture of iron and nickel the mantle mainly of iron and magne ium sili ate and the crust of siliceous rocks with an average composition somewhere near that of gran di rite *See* EARTH ELEMENTS (GEOCHEMICAL DISTRIBU TION) LITHOSPHERE GEOCHEMISTRY OF *see also* ATMOSPHERE BIOSPHERE HYDROSPHERE

[H D H]

Lithosphere geochemistry of

The study of the di tril ution of tl e elements and of their i otopes in the litho pl ere and [illegible] e es both pa t and pre ent whi h aff ct th distribution The lithosphere contains m re than 99% of the ma s of the earth It is [illegible]

far the most importa t eserv ir f almo t all f th chem al leme t and the p oce s in th lithosph e exert a dom nant nflu nce on many u la phe mena

Kno ledge f the di tribut on of the elements and of their i t pes in the l th phere is ery uneven Almost all of th ampl s wh h ha e a tu all been lyzed ha e come fr m th pre ent urfa e of th earth r f om a depth of le than 8 kil meters (km) S nce the a rage rad us of the arth is 63 1 km analyzed ampl s repr ent only scrat hi g f om the o term t porti n f th gl be The evid nce fo the chemical compo ition of th earth bel w the 8 km level s theref r la gely i d rect and mu t b ba ed on the d ta f geoph i s and inf rred f om meteorite an ly s Th mass a d l me of the e rth are k wn and theref its a ag den ity On the basis of tra el time curves f r arth waves generated by earthqu ke a d man m de e plo ons c nvinc ng mod ls of the changes with d pth in the d nsitv and in the l city of mpr ional and hear ves an b con t u ted These d ta tog the with nf rmati o th magneti f ld of the earth a d th mech ni l and thermal p pert s f the earth c ntribut t th f nd f informat n u ed in truct g th pre ntly a epted mod l f r the chem l t ucty e of tho e porti n of the e rth h h cann t be observed d r ctly *Se* SEISMOL OGY

The d ta n the hemi al omp tion of meteorites c mpl ment the geophy al data The m del based on geophy al d ta a d th e ba ed on meteorite d ta re p i glv m l a d pre ent epts f th maj r feat res of the chem stry of th rth int r r almo t rt lv rect f the maj element

S h a degree of ert inty c nn t be la m d f r m t of the mi o el m nt F we th n 10% f the h m al element a nt fo r 98% of th ma s f th l th phe e Th abund e f th m j rity f the element n the l thosph e i th ef well bel w 0 1% Th ad a ces in trac lem t a aly s i 19 0 h p ed th t d f th d trib t s f elements p e nt n rock n m nt les than 1 part pe million (ppm) o 10⁻⁴ th t the geo hem try f these el m nt n the pp r f w kil met rs f the lithoph e r bly well k wn H wev geo- chy al t h qu n t su table f h t d s th d p part of th rth d th e of m teo t dat alw b t by th un ert nty g rd ng the mpt o th at th re neces a ly f se pond b tw en the ab nd n e of l m t n th al zed m t r tes nd i th rth nt r r

Chemical compos tion of the crust Analy es n mbe ing th t f th a d h be made n gecl g m t i l All n ly all f the l) ed amples h m f om th ru t of the rth that from abo th M h r d c t t wh h l es at d pth f abo t 30–50 km nd th nt nt d at a d pth of ab ut 5–10 km under the oceans Altho gh many f the chem ical analy s are of omewhat q estionable ac curacy the large mas f a ailable chemical data is amply sufficie t to gi e an accurate de cription of the a erage compo ition an l of th compo t t nal vari ti n of the various types of geologic m t ial This information can l c mb ned with data on the relati e abundance f the ariou rock type in the upper portion of the earth s crust to give a fairly complete description of the a erage chemical c mpos ti n of th di ectly acces ible parts of the litho ph re

Some data on the ch mical ompo itic n of vari ous ediment and rock types are reprod i ed in the accompanying table A comprehen i e tatement of all the elements in each geochem cal pha e i gi en elsewhe e See ELEMENTS (GEOCHE ICAL DISTRIBUTION)

One of the m st tr king aspects of the data i the r lati ely mall range of chem cal compo i tion i the upper part f the litho phere Th ame do en r element p ed m nate in all f the maj r sed ment and ro k type All of the e except the carb nate rock c ntai rough ly b t een 40 a d 75% s lica SiO Th carb nate rocks a e al m t always cal m o c l ium m gne i m c r bonate often c nt ning an dmi t i of s li e us mater al Tl e rustal abundances of th major le ments and al o of the min elements therefore d not depend in v ry r tic l way n the r lati e pr port ons a gned to the v ri u sed m nt a d r k type n the e rtl s cru t Neverthele it ho ld be rem mbered tl at the cr tal abund n es l sted in the table a d in Figs 1 and 2 m t be re- g ded as er ges s bje t to revision

The cru tal abundan e data h been pl t ed on a l ne r scal in Fig 1 nd on a logarithmic cal n Fig 2 The fi t plot emph zes the fact of th pr po de nce f ert n l the el m nt of low atomic numbe N leme t w th atomic num be greate than 6 pre ent in the earth cru t with an ab nda ce greate than 0 1% The loga r thm c plot f F g 2 perm t th epr s ntati n f the b ndanc f all of th n tur lly o curring lem nt nd empha zes the fr q ency of cru tal ab nda c l es betwee 10 ppm (10⁻ %) and 0 1 ppm (10⁻) p rt cularly among the elem nts of h gher at m numb r The bro d f atures of tl ese f gures a now r a o bly w ll unde stood Th y a e the produ t of th pro s es of el n ent f rm tion of the proces s op ting du ing the f rmati n of the rth d of th p o es s w th th arth wh h h ve p rated b th the di ec t n of hom g n zat n and d versifi t on of the hem al c mpo t on of th various p rts of the rth S e ELEMENT (COSMIC ABUNDANCE) ELE MENTS AND NUCLIDES (ORIGIN)

Chemical composition of the mantle Th ea th mantle con ts of mat ri l between th M h o d ontinuity mark ng the ba e of the n st nd the di nt nu ty at a d pth of 2898 km ma king the t limit of the arth s o No nequi cal p ece of m ntle h s ev r been

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Lithosphere geochemistry of

The study of the distribution of the elements and of their isotopes in the lithosphere and of the processes both past and present which affect this distribution The lithosphere contains more than 99% of the mass of the earth it is therefore by

100
50
40
30
20
10
0

HH Li Be B C N O F N N Mg Al S P S Cl A K C Sc T V C Mn F C N C Z 30 Ga Ge A Se Br K Rb S Y Z

10 20 30 40

t m mbe

Fig 1 Cru t l b d f l m ts f t m mbe 1–40

this i d ti ctly p obable b t that th a e atomi mbe { re mater al i les tha th t f iron. S lic n h s th fo bee uggested as a importa t t tuent f the e but e al oth alt rn ti es ar t lea t p ble d the p obl m rem in pe at th t m

Exc pt fo th minor elem t d ta from th me tallic ph e f meteorites th i f rm tion as r g rds the min r eleme ts n the re m l ly scanty

Important crystalline phases The maj r po *tio of th l tho phe is* l d In th crust the solid a e p ed m ntly well ry t ll z d nd th is alm t c rt nly true f r the m tle as w ll Or g n a d l on a th m t al und t le ment in th cru t d the ma tle a d th s l d ph ses e lm st all *e the o d s* l cates Since th proces es desc bed b low depe d t a co d rabl e tent n the pr pert es of th m po ds th ery t l ch m try f th m j r m n eral ph es is b efly reviewed t th s p nt S e MINERALOGY

Oxide st ct es Th tru tu f m t of the rock f rmi *g o* des is mpl In all f them O the l rgest i n d d term e th t ct r l f me- ork In pericl s MgO the O io s a e ub lose packed a d the Mg²⁺ cc py th octa hed ally oo d ated hole betw e neighb ng O ns. I the p l gr up R'''R O the do l t R ons a d the t i al nt R n g occ py e th t trahed lly ctahed lly coord at d h l betwee c b c cl e-pa ked O i s. H g n l l e p k g of O io s is f d in rundum Al O and n r l t d m n l h a lme *i F T O* nd ge k l te MgT O

In these tru t res the cat n g n c upy 4 or 6 oordinated h les n the O f mew rk

Sil cate st uct es Th e tructures e *nor* m lly more compl cated than th o de *t uct es* Th b i u *t of str t i* the lic n-oxyg tet hedr S O ns *ting of a S⁴⁺* ion at the cent f a t t ahedro wh se c ne are oc cup ed by th *ent of* O io These tet hedr ns may be jo ned by cati n s in the ol *vines (Mg* Fe)₂SiO zi co ZrS O or the g rn ts R R (S O) *In th* st ctu es th [S O] group erve a f n t n im l r t th t f the [SO₄] g o p in th ulfat The stru t of the ol ine s m la *to th t of th* spi els i fact l ne n ert to p n l f m t high p e su es

In the majority of l cate c mpo d th [S O ⁴⁻] gr ps p lymer ed S h p lymeri zati n m y lead t *group of tw three* ix tetrahed s to ffecti ely *nfi* te h n r do bl h ins to sheet truct res to thr d me nal netw k *f [SiO] gro p The* phy cal p pe t es of s l t m eral ar *ofte* r l ted n a im pl m ne to the type of p lyme *zat* n f the [SO] gr p Th cle vag pla es f the py r enes the amph bol s a *d the* feld pa are p r llel t *the effect ely* fi t ha d ubl ch n char t tic of the e m eral groups Sheet f [S O] t t ahed o are par *llel to th* pr o ed lea *ge of th* m ca cl ys nd chlo- rite g p m ls The *unif* rm three d m n n l n two k of q artz i *flect d* the la k of l av g th m e l

The th impr bable f mulas gge t d f m y s l c t m ls by h m c l a alys be-

Average chemical composition of sediments and rocks

	I I	S O₂	TO₂	AlO	FeO	FeO	M O	MgO	C O	N O	K O	PO	CO₂	H₂O
Sediments and sed mentary rocks														
Calcareous sand oozes	1	18 8	0 3	ᴗ1	3 8		0 4	1 4	39 0	0	0	0	°9 8	
Red cl y	2	5 8	0 9	16 4	9 0		1 0	2 9	~	1		0 3	4 6	
Silic ous oozes	3	55 5	0 5	1ᴗ 1	5 8		0 (	3	9	1 0	--	0 3	6 9	
Average pel gic sediment	4	8 5	0 4	8 1	0		0 6	1 8	30 ᴗ	0 8	1	0	9	
Co mpo iti n of suboceanic sediments	5	43 °	0 7	11 (	4 6	0 6	0 3	4	-1 1	1 1	1 8	0 1	1	
Average ediment	6	44 5	0 6	10 9	4 0	0)	0 3	2 6	19	1 1	1 9	0 1	13 4	
Aver ig shale[d]	7	58 10	0 6	15 40	4 0	4		- 44	3 11	1 30	3 4	0 1	63	5 00
Average sandstone[d]	8	78 33	0 ᴗ	4 7	1 07	0 30		1 16	ᴗ 0	0 4	1 31	0 08	5 03	1 63
Average limestone[d]	9	*5 19*	*0 0(*	*0 81*	*0 54*			*8)*	*4*	0 0	0 33	0 04	41 54	0
Average sediment[d]	10	ᴗ7 9	0 ᴗ	13 39	3 4	- 08		- 6	89	1 13	86	0 13	38	3 -3
Igneous rocks														
546 granites 4	*11*	*70 8*	*0 4*	*14 6*	*1 6*	*1 8*	*0 1*	*0 9*	*0*	*3*	*4 1*	0		
137 granodiorites 6	1	67 -	0 6	1 8	1 3	6	0 1	1 (	3 6	3)	3 1	0 °		
635 intermediate igneous rocks 13	13	ᴗ4 9	1	1(7	3 3	5	0	3 8	6 6	4	3 -	0 4		
198 basalts 19	*14*	*49 9*	*1 4*	*16 0*	*5 4*	*6 5*	*0 3*	*(3*	*) 1*	*3 -*	*1*	*0 4*		
18- ultramafic r cks 2	15	44 0	1 7	6 1	4 5	8 8	0 °	- 7	10 °	0 8	0 7	0 3		
Averag igneous rocks 11	16	60 1	1 1	1ᴗ 6	3 1	3 9	0 1	3		3 9	3 °	0 3		
Metamo phic rocks														
- 0 qu rtzofelds athic gneis es 50	17	0 7	0 5	14 5	1 6	- 0	0 1	1		3	3 8	0		
103 mi a schists (1	18	64 3	1 0	1	1	4 6	0 1	7	1)	1 9	3	0		
61 slates 6ᴗ	19	61 8	0	1) 1	3 3	ᴗ 4	0 °	- 9	1 0	1	3 8	0 1		
-00 amphibol te 68	0	0 3	1 6	15 7	3 6	7 8	0	(0	9	)	1 1	0 3		
Crust of the earth														
Average compo ition	°1		1 6	1 3	8	5 8	0	-	8 8	9	1 9	0 3		
Average c mpo ition[d]	°2	(0 18	1 06	1 61	3 14	3 P8		3 6	1	3 91	3 19	0 30		

Ba d on sum maries by A I oldervaart in *Crust of the Ea th* Geol Sc Am Spec I aper 6 19 n l by B Mason in *Principles of Geochemistry* d ed Wiley 19ᴗ8

[a] Values omitted where sampl s were calculated water free

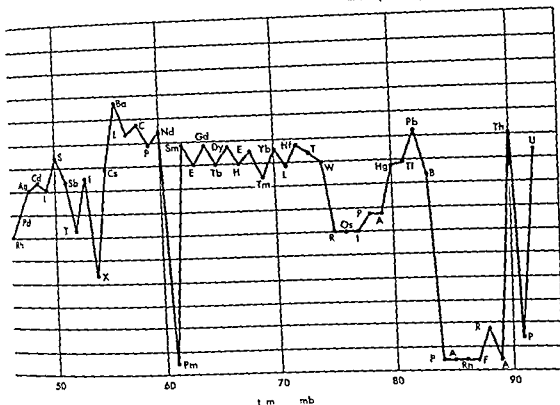
I rom Poldervaart fi ure if gi en r fers to index number as used in P ldervaart

[d] F m M son

analyzed although the olivine bombs ejected from a number of volcanoes may well have been derived from the mantle Pre ent thinking regarding the chemical compo ition of this portion of the earth is therefore ba ed almost entirely on ge phy ical evidence and on the circum tantial meteorite e i dence The latter line of evidence ugge ts that the composition of the mantle is not very different from that of ultramafic igneous rock (see index 15 in the table) the geophysical evidence is in sub tan tial agreement with this hypothe i H wever the evaluation of the density and elastic wave propa gation data is at pre ent rather tenu us since ol ervations on the tate of silicate minerals at tem peratures and pre sure characteri tic of the mid dle and lower portions of the mantle are still very fragmentary At pre ent it seem likely that silicon oxygen magnesium iron *and calcium are in fact* the major elements in the earth s mantle but the cry talline pha es in which they occur still remain to be determined It i al o very likely that the mantle at lea t in its upper porti n i more heterogeneous than has u ually been a umed an l that it tructure may be almo t a complicated a that of the cru t

Knowledge of the abundance of the minor ele ments in the mantle i even more fragmentary than that regarding the major element Only *in tl e ca e* of the radi active element can s mething be said independent of the meteorite mo lel The al undance of the e elements mu t l e l w en ugh to pre ent melting of the mantle and thi mu t mean that the *al undance of p ta ium uranium an l th rium* must l e very much less in the mantle than in the crust In theory heat fl w mea urement can gi e more definite indi ati n al out maximum c ncen trations of the e element in the mantle However the c mplexitie intr duced l y radiative and p i l ly convecti e heat fl w in the mantle introd i serious complications int the interpretati n f surface heat fl w mea urement S e FARTH (HEAT FLOW)

Chemical composition of the core Tl e re f *the earth con i t of the material l etwe n a l pth* of 2898 km and the center of the earth I r blem similar to tho e be etting the stu ly of tl c mp i tion of the mantle al o limit study f th c re Again all data are circum tantial Tl m le ri data ugge t a c re f metalli ir n with an admix *ture cf nick l Th* geo phy ical data in l at tl t



t m mb

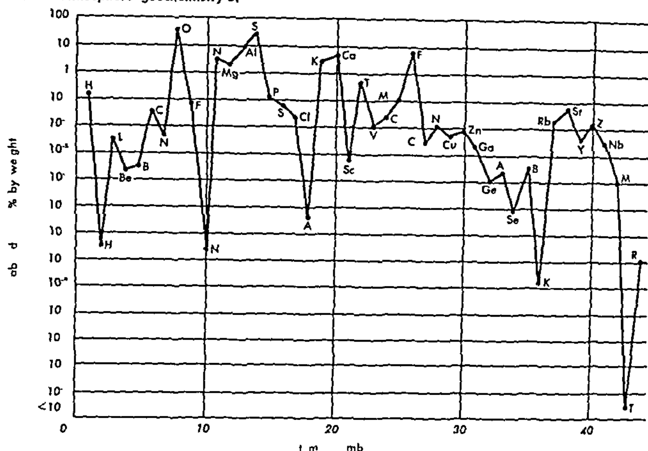
mt egion l re. rv r o l al erv i de- m ded by many pr bl m For ta e n t dies f the ge of n ig eous ck unit th system of terest d ıdual ry t l f th m eral m n r l u ed fo datı g p p e The p obl m in ge ral terms thu c ns t f d termin g the event wh ch h e tak n pla e w th n the sy tem f terest and the e t t of exch ng b tw en th ystem a d t en nment *Se* Rock (AGE DE TERMI ATION)

Cha ges n y tem are f ri u k nd C r ta n system p l bly ha e h ng d ath r l ttl in s ze a d mp t n d r ng mu h f earth h st ry Th co e of the rth may well b on h ys- t m Other y t m h p ob bly grown te d ly thr gh t rth h t y The hyd o pher t l m t certa ly a c e n p nt and th e rth ust it lf m y well h c e d pp ec bly n l ume at th xp n f the e th m ntl Still other y t m th bi ph f r o h e pr b bly ff ct t d app ably n olum d ring geol g c tim All f thes y tem r t l t part ally t t d pe dent s that th dy m f the e rth re ex eed gly c mpl t d and g n r lly d f ficult t ed t m g ble p port n

The major cycle M ny f these pr esses pa t p te t what h met be k wn th m j r cy l wh se m t mp rt t a pect ar h wn in Fig 3 Th w ath r g f igneou sed m t ry and m tam rphi ock t th l tho phere- tm s- ph e bo d ry prod es ed m nt These ar b r ed d mp ted at d pth to p od ce ed me t ry rock At m e elev ted t mpe t o pres- re r b tt ed me t ry r k recry t lliz to met m rph cks At t ll h ghe temperatures parti l r omple te meltı g m y prod e rock melt wh h ool t f rm gneou r ks Expo u of these r k to w athering pr e ses th n renew th y l

We th ri g p o e es Th hem al d sequ lib- ium betw en the tm pher nd many of th r ck typ s e po ed t t s o e of th imp ta t fa ts of ge ch m stry The re t ns of hyd ation l ti n o dat n nd ca b nat on charact ri tic of the z ne f w ath r ng r pa t f th ontinuing pr s of the pp o h to equ lib um t the l tho- ph e-atm phe bo nd ry

The effect f th atmospher ı ı e and gro d wat n ari us m n al d pend n the stab l ty n th typ of v nm t and on th rat at wh h u stable m ne als d pp ar in fa r of t ble ones Th feldsp rs pyr xe es and ol ı e re am ng the m t re d ly destr yed rock f rm ng m n al I th s typ of n ronment, the remov l f the l rg r c tions (N K Ca++ Mg++) is u u lly ap d d the remaı g m nerals re usually hyd ted lum n m s l c tes ont ning no e f these atı n o c ntaı g them n ap- prec ably m lle q tities th n the orig nal m ral Som un t bl r k f rming min rals act m h m l wly with the tmosph e M gne- tite F O s n of thes Th stabl ox de f n n equ l b m w th atm ph ric xygen ı h m t te, Fe O y t magn tite a comm n c n tit ent f b ch sa ds ac umulate f the res due f w theri g p o es es Finally mı e als s ch as



F g 2 Crustal abundance of elements of atomic number 1–92

fore the advent of x ray crystallography were shown to be quite natural results of their often compli cated silicon oxygen framework structures and the development of the crystal chemistry of the sili cates has been one of the most significant contri butions of mineralogy to geology since 1920 *See* SILICATE MINERALS

Processes involving the lithosphere The earth is not at rest Earthquakes volcanism and moun tain building the three major manifestations of *disequilibrium at depth are evidence of* wide spread physical and chemical change below the surface of the earth Erosion and chemical weath ering are evidence for the pronounced di equilib rium b tween the atmosphere and the lithosphere Chemical changes are thus taking place at various levels in the litho phere and at the boundary be tween the lithosphere and the atmosphere bio sphere and hydrosphere The proce es taking place at the earth s surface can be ob erved di rectly and are therefore more completely under stood than the processes taking place within and below the earth s cru t Yet it is just the proce se at depth which are of primary interest as a key to the history of the crustal evolution of the earth

For most of the element the earth can be con sidered a closed or an almost clo ed sy tem The two major exceptions to this rule are hydrogen and helium which e cape at significant rates from the upper *atmo phere Hydrogen e cape has* prob ably played an important role in the evolution of the atmosphere from a methane ammonia arg n water vapor mixture to its pre ent highly oxidized state Minor exceptions to the rule are tho e ele ments which are entering the atmo phere as constit uents of meteorites or as co mic ray particles or which are swept up by the earth It eems unlikely that these additions have affected the chemistry of the earth materially

The earth can therefore l e regarded a an es en tially clo ed system consisting of a numl er of re ervoirs The exchange between these re ervoirs may be appreciable and is often a complex func tion of time In times comparable to the age of the earth the mass and composition of various re ervoirs have changed radically The l asic problem in the tudy of the dynamics of geochemi try thu consi ts of defining suital le re ervoirs and of de termining the nature and the rates of the proce es which are operating on them today and which have done so in the past

The primary divi ion of the earth into the litho sphere hydro phere and atmosphere is con enient since the limits of the e reservoirs are rea onal ly well defined and their contents of apprecial ly dif ferent kinds The bio phere has a somewhat differ ent status since in space it o erlaps the other spheres completely The primary di i ion into f ur spheres is too coarse for many pr l lem in earth science The subdi ision of the lith phere into crust mantle and core is evidence of thi an l th further subdivi ion of the cru t into sediment and sedimentary rocks metam rphic rock and ig eu rocks was implied in the di u i n of tl averag chemical compo ition of material in these cat gories Further subdivi ion of these larg nit

66 1958 B M so *Pri c pl of Geo h mist y* 2d ed. 1958 A Muir (ed) *Geochemistry* pt. 1 19.4 A P ld rvaart *Cru t of the Earth* Geol Soc Am Spec. Pap r 62 19-144 1955 K Ran kama a d T G Sah ma *Geochemistry* 1950 O F Tuttle and N L Bow n *Origin of G a ite in the Light of E p rim tal Studi s i the System* NaAlS O *KAIS* $_3O_8$-S O_2-H O Geol S c Am Mem. 4, 1958

Litopterna

These we hoofed herb re confined to th Ce n zo f South Am r ca The rde wa well ep resented from th Paleocene to the Pl i tocene and ppa ntly ro e on that ont nent from a on d larth a ce try By later Paleoc n t m two main li es f des ent were clea ly demarcated The *Pr t theri dae* (Fig 1) displ y d a rema k ble e l t n ry co e ge ce w th the hor es in tl ir dentit n and in educt on of the lateral dig ts of the feet. The foot w s educed to a ingle med an toe by e rly M o en t me The member of the M rau h dae (F g 2) we e pr port n d m b a n th cam l a d by late T rt ary tim h d mila ly lo t the rt b al rt r al canal f the c rvi al ert b e They early dev loped a tend ncy t ard et cti n of the nasal bon by lat T rti ry time th n l open g w tu ted b e th e es top f the kull Th p salization has been th ght to i d at the p es n e of a tru k r p rhap do lly tuated n t ls adapted f r bme ged amph bi i tenc Th ee fun tion l d git emain n th feet f e e th m t d n ed m c u hen id S e CONDYLARTHRA

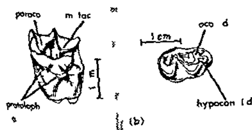


Fig 1 ( ) Upp r d (b) l w m l f P t the- ea ly M oc p t the d l t pt m l m th So Cru format f P t g A g t



Fig 2 Sk ll nd jaw f Th d g H m n early M oc m cr h d l pt f m th So t Cru form f P t g A g t (Aft W S tt 1910)

Both g oups hare the foll w ng characters l ld typ c l f r th order The kull wa witho t xpan on of the temporal or squamo al nu s as in the notoungulate a pc to bital ba wa present Den t tion wa primiti e w th full eutherian formula and a tendency to reduce inci rs a id pper ca n e teeth cheek teeth were unred i ed low to h gh-crowned the po terior premolar lecoming m lariform The upper mola s we e q adrate the p racone and metacone were cres ent c the pro toloph was pre ent but the metal ph ab ent The l wer m la were b r entic the ento onid was not olated but j i ed to the p te io nd of the t oth. The feet we e functi nally 3-toed or red iced to a gle digit the weight borne by digit three See DENTITION

The earliest known mammal an f una n South Am ri a (late Paleocene) ontained rep resenta ti es of b th gr p of litopterns By Oligoce e a d Mioce e t me th litopterns ea hed their g eate t recorded *abu dance* The p oterotheres d d n t urv the Pl o e nd of th macrau he- n d only the large *Mac auch nia* ry ved until Ple tocene t me [R H T]

Liver

An organ cha a teri t f all *the* ertebr tes It i not found in other an m l however *org ns* of m lar funct uch the *h p topa creas* of cru ta e ns exi t in *in ertebrat s* Th l er i an o g n z d mas of cells through which en u *blood* fl w as t return f m the *nte tine t* the h rt. It s co n ted with the test ne by y tem of du ts In the n rm l adult, t s t ble organ n that its c ll divide nly a ely and t c t hitec ture s fixed It is however an acti e orga the largest gl nd in th body and ha a l g numbe f f n t n Among th m t imp rta t *fu* t o f th l e re the to age of food tuffs ar d ta mi th l an g f the blood b det fi atio nd ph gocytos th limin t n of wa t p d u ts th prod ti n of auxil ry digesti e sub- tances th destruct o *or in t* ati n f *ho* m ne the p od et n f certain bl od pla ma mp e t d h m t p s *the* p od ti n f blood cell i the embryo

Th li e ece es a small amount of its blood upply d r ctly fr m th heart through the h p t c art ry b t th large p *rt i* recei ed from th wall f th gut th ugh th p rt l e n This l r g with t product f d gest n a d oth ubstan es ab- o l ed th ough th ntest l mu Th p rt l e n a d hepatic artery nt r the l er tog th r and both b a h epe tedly Th b n h s tr l ide by d w th n m re branches of tl bil d ct and a lymph es el th portal ca l These a cont n l i o d f c ect e ti u kn wn a Gl so p ule In pl c of c p llari tl r are s mewhat l rg es l *th* in d with phago- yt k pffe ell thei wall Th inuso ds fi lly j n t f m the hep tic ns th t d in the l er nt th *nf* i vena a a The l r cell are r ged i d plates perme ted by th net

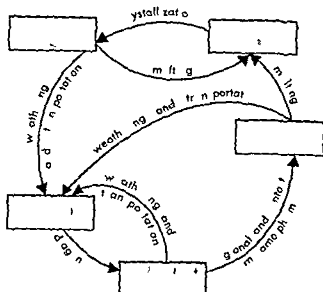


Fig 3 Important featu es of major geochemical cycle

quartz, SiO and calcite $CaCO$ are stable in the zone of weathering They will only dis olve in rain and ground water until the e waters are saturated with re pect to SiO and $CaCO_3$

The processes of weathering and transport thus alter exposed units of the lithosphere in the direc tion of equilibrium with the atmosphere but often do not reach this state completely *See* WEATHER ING PROCESSES

Sedimentation and diagenesis The proces e which take place as sediments enter the oceans are complicated but normally alter their over all chem istry and mineralogy only slightly However evap oration in closed or partially closed basins can lead to the formation of evaporite beds of com po iti n very different from that of the normal detrital sediments Sequences of ulfates carbon ate and halides formed in such environments are therefore inter persed with sediments c n isting largely of ilicates and oxides in tratigraphic columns of many areas The over all compo ition of these columns is then on the average appreci ably richer in carbon dioxide water chlorine nitrogen sulfur and boron than average igneous rock This is not unexpected since CO and H_2O as well a g ologically important compound of the other elements are in a ga eous state at the tem perature of rock melts and are undoubtedly l st preferentially to the earth s surface and incorpo rat d in ediments *See* EVAPORITE (SALINE) FUSED SALT PHASE EQUILIBRIA

After deposition most sediments become buried They therefore are subjected to higher tempera tures and pre ures Under the e condition cemen tation a lo s of poro ity and a certain amount of recry tallization take place and and tone lime tones and shales (the major ty es of sedimentary rocks) are formed Such changes are perhaps mo t pronounced in the ca e of carbonaceous sediments Peat becomes dehydrated and pa es through the variou grade of coal approaching the composi tion of graphite with increa ing depth of burial *See* DIAGE E I

Metamorphism At temperatures and pre ures higher than those normally encountered in dia genesi important changes take place in the min eralogy and texture of mo t sedimentary rock These change are termed metamorphi m and lead to the formation of metamorphic rocks It is obvi ou that there is no harply defined boundary be tween diagenetic and metamorphic proce es *See* METAMORPHISM

Metamorphism may either be local in nature a in the vicinity of a body of intru ive igneou rock or it may be regional occa ioned by a rise in tem perature pressure or both over a con iderable area Reactions in both contact and regional metamor phism are determined by the prevailing pres ure and temperature by the compo ition of the rock units and by the kinetics of the po ible reactions Understanding of these reactions has been increa ing especially ince the introduction of water as a component in systems studied in the laboratory and the investigation of material tran port during metamorphism Metamorphic reactions are appar ently nearly i ochemical although the tran port of certain elements suggests that mall volume of rock undergoing metamorphism cannot afely be regarded as closed systems *See* SILICATE PHASE EQUILIBRIA

Melting and crystalli ation At still higher tem perature melting of rock units begins The com position of rock melts depends on the compo ition of the parent material on the ratio of liquid volume to that of the solid residuum on the temp rature and pressure during melting and on the degree of equilibrium attained between the liquid and solid phases The liquid fraction may mo e into higher levels of the earth s crust and may even break through to the surface as lava or other volcanic products At the lower temperatures higher in the crust cry tallization normally takes place the na ture of the resulting olids is determined largely by the initial composition of the liqui l an l l y tl conditions prevailing during cooling With the aid of pertinent laboratory studie the relati n hip between many diff rent igneou ro k types from th highly silicic granites through the intermediate gabbros to the ultramafic perid tite and dunite have been satisfactorily e tabli hed alth ugh the major que tion of the origin of the bulk f the ili ceous rock of the upper crust i till larg ly un an wered *Se* MAGMA

This que tion leads directly to the que ti n of the nature and extent of exchange b tween mantl and cru tal material and to the ex h ng f mate rial between the core and the mantle H wever a l ng as knowledge of temp ratur i the mantle and core and of th behavior and mov m nt of material in the mantle i a circum cril d a n is at present the di cu i n of these pr be low the l a e of the cru t t n t very fruitful

(H I H)

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Litopterna

These w r hoofed h b vo es c nfined to the Ce nozo c f South Am rie The order wa well ep- resented from the Paleoce e t the Pleistocene and app rently arose n th t ont ne t fr m a c n d larth an estry By late P leo ene time two m in lines of desce t were clearly d m r ated Th Prot therıdae (Fig 1) d played a remarkable ev lutionary n erge c with the h r e in their dent ti n a d n redu tion of the lateral d g t I th r feet. The foot was redu d t i gle m dian toe by rly M o e e time The memb r f the *M ra hen ida* (F g 2) w re p op rt ned m h i th e mel and by late Tert ary t me had s milarly l t th erteb al arterial an l of the ervic l ertebra They ea ly de l ped a t oden y t w d tra t on of the na al b n s by l t T rt ary t m the a l open g was t at d bo the eyes o t p of the k ll Th pec aliza ti n ha be th ught t ind cate the pres c of a trunk p ih p d all tuated no tril adapted f bme ged amph b ous x stenc Thr e fun t nal d git em in i the feet of n the mo t ad an d ma ra ch n d S e CONDYLARTHRA

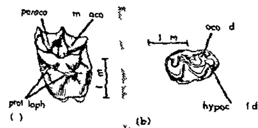


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Liver

An rgan ha a teri tic of all the ert b ates It is n t fou d in other an mals howe er o g n of mil r fun t n su h as th l p t pa cr a f cru t ceans e t in in rteb ate The li er an or g n zed ma s of cells through wh ch en u blood fl ws a it eturns f om the int t ne t the heart It c nected with the ntestine by a system of d ts In the n rm l adult it t bl organ in that it c ll d d nly arely and i vi architec t re is fix d It s howev r an a t e o gan the largest gl nd th body and h s a la ge number f fu t n Am g the m t mp rt nt f nct ns f th l e ar the stor g of food tuffs and vit m s the cl n ng of the blood by d tox fic t n d ph gocyt s th elim nati n of wast p od u t the p od tion of au il ary dige t e ub- t n s the destru t on r inact at on of h r m nes th p oduct on of ce ta n blood pla ma mponents nd h m t po s s th p od t on of blood c ll n th mbryo

The l re es a small a ount of its blood s pply di ectly f om the he rt th ough th hepatic rtery but the l rg r part i rec ved f om the wall f the gut th o gh th portal e n Th brings w th t p od t of digest n nd oth r sub tances ab- o bed thr ugh th intest nal mucos The portal n nd hepatic rtery ent th l r togethe nd both b n h pe t dly Th b a h tra el sid l y d w th ne o m e h n bes f th b l duct and a lymph v sel n the p rtal c al Thes c t ed a c d of c nn t ti k wn as Gl n cap le In pla e f ap ll ri th e are m what la ge es el the nu d with phago- cyt c o K pff cells in th i wall The inuso ds l nt the inf e a ca Th li er ll e rr ged n e d pl tes n rm ated b

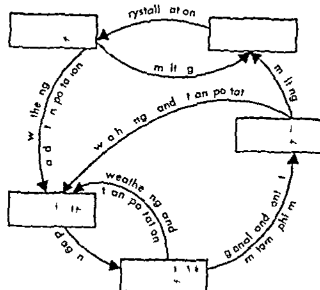


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[H I H]

Bibliography W Fit l Stru tural (n t in (ystallin System s and Th i Imp rt l e Ce logical I roblems Ceol Soc Am St l per

th body and th l er is ne of the new es els arise in mese chym w thout any c n ection with l ady establ hed es el T th s th re are two repl es (1) th sem t c qu t on of a defin tion f m sen hyme and (2) th bs rvati n th t hat seen the r gin of a blood ve sel is the appr ra e f the l men ot the o ig n of the cell Bec use the ll of the me nchyme come from various ou ces a d e entually develop al ng spe- c lines, th po ib l ty th t they po es d ffe ent potenc es annot b ruled ut It s therefo e possible that end thel m of the blo d ssels ti ue specifi f m the t et

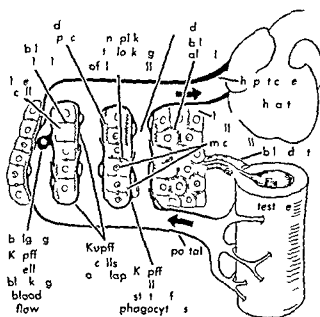
Role of mes d rm The co ept of the me n chym bec m s st ll m imp rtant when the c n tributi n of th mesoderm to the development of th li r is cons d ed The e an be little doubt th t some e tebrate f rms th splanchn c esod rm mesothel um i the ic nity of the li er l ge prolif te a d co tr b tes ells that comb with the e dod rm l anlage t p oduce th liver ma Th prob b l ty is great th t thes cells becom ular t ssu and hematopoiet c ti e. It h uld be emph zed that the contribu ti f th mesoderm is most c sp ou n f rms th t h e little r y lk sac I the chick and the lizard, both of hi h h large y lk sac no uch co trib t n i m de The bl od isl nd which re th a l g of the ascular end thel m nd hema t po et ti e acc d ng t the ngi bla t n cept, arise in the pl h m sod rm of the y lk c, and e c n p lv re t ted to thi a in th h k It ha been assumed th t the hem to p et ti e d lopin at first in the bl od islands seeded int the l er f om ther and lat t the pleen and b marr w they de vel p Th e i c n d bl e d ce that such seeding occur especially f om th blood types f freemartin twi n c ttle d i mammal nto h h bo m rr w h been inject d foll wi g ira irrad t n In both c se the f ign ed blood c ll typ c ti s t be p od ed indefi n ly di ati g th t s cce sful t a plantati (hem topo et c t ss ha oc ed

I thos verteb tes i whi h the yolk c i s- tiga l, blood i l nds do app on the tige, b t th ghbor g plan hn m od rm makes cont but n t the l e The pl hn mes d m at the l r or te tin l p rtal wher the li er anl g rises, i d e tly o t u by way f the yolk t lk w th th t f the y lk ac, whe e th bl d l nd lly a i S em gly the wh the y lk sa i ed ced the pot nt l ty f f rmi g n bl st xt nded to the a t r r i t t l port l g n The ell nt buted by the spl n h n mesod rm r by m en hyme" d d f m it m devel p nt h m top t c t s e cell c co d g t some i vestig t r It s not w thy t at ion f th m chym e m t devel p int con ect t u Th c necti e t f th l rises f m mesen hyme th t l t in ade the l er ma th th b hi g p rt l i d h p t art ry

Structural development The de elopm nt f the cytoarchitect re f th li er and f the bile d ainage sy tem ha been tudied thoroughly n mammal The anlag of th li er i ordina ly sa d to d el p nt a ma of anast mosi g co ds with the nu o ds f rming a network in the spaces The process of formati n was considered to c n st f a pen tration of a larg r ein by the c ds in s ich a way that they become completely surro nded by nd thelium Th educes th former cyli dri al e el to a network Th s p ocess was named inter c escence by F T Lew s The concept of the li er cord has bee challenged with onside abl justifi cati n by H El a si ce the adult the paren hymal cell cur n plat s rather than n cord of pair of cell as is freq ently d agr mm d How ever n the chick at l ast a tudy of the early de elopme t of the pa enchyma h s l d t the con lu n that the bas f rm i deed th cord with the pl tes pr d ced by widen g f the cords to form wh t has been de gnated muralium by J K ng bury rather than a netw rk In a y case there are at first neither bile cap lla e n a bile drai ge ystem The part f th di rtic lum that is t fo m the b le d ct nds bruptly at the l er mass and ts ws of cells are continu us with the ord f th p renchym The li r h been likened t th glands f the dig ti e t act with the l e ords eq lent t th al eolu and the bile c pill ries to their lum s The p ttern of de lopm nt howe er q te d ff rent for the d ct does n t b nch ep tedly with a presumpt e al olu at th end f each b anch b t rath the o d th mselv b nch f eely d n t m e to f rm a three d me s onal netw k i which no em bl e f the l e l r st u tu e can be d o er d There at this stage n i dic t n f l b lar st uc tu unle s th wh le m s is con dered a s gle lobule w th bl d enteri g thr ugh a ein at o e end pa g th gh a scul network and l g by ei at the the

Growth As the m s g w t engulfs the p t l ein o i n w f eq e tly id the portal ve p trates the m s alo g with a sh ath f c nn c ti e t ssue The p rt of the d erticulum th t will l t bec me the b le du t r t at with the stump of the p rt l ein d does n t p trat th gr w i g mas lth gh t r tains ts tinuity with the li ords The b hes of the bile d ct that company the b an h of the p rtal ein with n the l er ma re de d f m the co d of ll d j t t the ein d n e ti e tis The b le p lla ha e ari n ppar ntly b g n ng spo- d cally d ffe nt pl s t ra d m n the a s t mo ng netw k f p e hymal ll cords to f rm two k th t ti ally e pa d unt l they b m co fl t, prod ng a gle c t o n tw k.

D t f rmation In th e c ds next t th pe e t t g port l e n nd n ect e ti e th ell e t to the t e ti b c me fl tt ed d the lum w den t p duce th p ct l g go d l ed a the c al f Hering The de of this



Fg 1 Schemat c d agram of the l ver as a mass of cells (st ppled) based on elect on m croscopic observa t ons

work of sinusoids The whole parenchyma is di vided into architectural units the lobules A lobule is a thimble shaped mass of cells hexagonal in cross section and drained by a central vein which is a radical of the hepatic vein Five or six portal canals course along the periphery of the lobule Between the cells of the hepatic cords or plates are minute ducts the bile canaliculi that form a continuous network throughout the lobule and at the portal canals drain into the bile ducts carrying the bile ecreted by the cells to the intestine

EMBRYOLOGY

General theory According to conventional ac count the liver arises as a diverticulum from the floor of the foregut This soon l ranches into two the anterior branch destined to form the liver parenchyma and the po terior the cystic duct and gallbladder Of particular importance is the re lationship of the growing liver mass with the large veins that course along it from the yolk sac allan tois and the posterior part of the body As the liver grows and meets the e ve els the ves els are pene trated and broken down into a network of small ve els in the spongework of parenchyma Through out the eml ryonic and fetal period as long as the yolk sac or allantoic circulation per ist channels carry the major part of the blood through the liver ma s but with the ces ation of the e extraeml ry onic contril utions the e channel cl e and the portal vein the sinu oid and the hepatic vein of the adult form remain (*see* FXTRAEMBRYONIC MEM BRANES) The history of the ves els and their re lation to the liver varies greatly in different vertebrates and it explain the variation of venous patterns in adults from form to form as well as the many anomalies found

The actual form of the liver in the vari us erte brates and in individual species implie that it is extremely pla tic It has been described as a pace filling ma s that accommodate it elf to the pace available This concept is to a certain extent sup ported by the changes in hape that may occur as a growing tumor competes for space or as the hape of the space is changed by tight lacing of a cor et It seems clear that at least from the point of view of function the history of the ve els and the hape of the liver as a whole is quite irrelevant A long as the basic pattern of portal vein sinu oid and hepatic vein persists the liver functions normally

Classical theory From the point of view of the clas ical germ layer theory the liver has three sources of ti sue (1) the parenchyma is entoder mal arising from the floor of the foregut (2) the sinusoid linings and the hematopoietic cell if present are from the angioblast (3) connective tissue particularly in the portal canal is from the mesenchyme The surface for the mo t part is covered by the mesothelium of the peritoneal lin ing In recent years almost every aspect of this point of view has been challenged It has been a erted that new endothelial lining of the inu oids and possibly the hematopoietic cells ari e in situ from me enchyme incorporated in the growing liver mass and are thus independent in origin from existing vessels or from the blood i land and hence independent of anything corre ponding to the an giobla t It has al o been a serted on the l a is of an extensive review of serially sectioned embryos of a large number of species of all cla es of verte brates that a sub tantial part of the parenchyma itself may be formed from me enchyme derived from thickenings of the planchnic me derm much as the adrenal cortex and part of the meta nephros are formed The description of cell ori gins from static stained ections may lead to a confu ed and chaotic picture when explanation i difficult and uncertain On the other hand the study of cell origins by experimental techniques has proven difficult

The cell origins of various structures derived from the ectoderm has been extensively studied in the amphil ian and avian egg and the role of inter relations of tissue in induction beautifully demon strated experimentally Nothing like thi seems to have l een demon trated for structure derived from the entoderm It seems that in l oth amphil ian and the chick the e tructures are self differentiating from very early stage perhap existing as part of the l a ic pattern of the egg *See* FATE MAPS EM BRYONIC

Role of mesenchyme The que tion of the c n tril ution of the me enchyme t the va cular pattern and even to the parenchymal ma i of a different s rt The angi l la t concept would derive all en lo thelium from the original l lood i lands by a proc es of progre ive sprouting It validity ha been repeatedly and emphatically challenged There e m little d ul t that after the pattern of l lood and lymph ve els i defnitely e tal li l l n w e el d ari e by spr uting from ol l one H w ever it is definitely a rted that in many part f

the bod nd the li er is one of the e new ves els m anse in mesen hyme w thout any connect on with alread establ hed e. els To th is there are two repl es (1) the semantic qu ti n f defin tion of mese chyme and (2) the observat on that what is seen i the o igi of a blo d es l is the appearan e of th lumen not the or g n of the ell Beca se th e lls f the mes chyme c me from various sou ces and ventually d elop along spe- f lines, the pos bility th t th y p s e d fferent poten es c nnot b ruled t It the ef e pos- sible that end theli m of the blood e els ti sue spe fi f m th ut et

R le f m s de m Th concept f the mese chym becomes till m e imp rta t when the con trib u n f the me oderm t the de elopment of th l e dered There can be little doubt that, in some tebrate f rms the planchn mesoderm or mesothel m in th ic ity f the liver anlage pr lif rates and ont ib ites ells that combine with the e dod rmal lage to pr duc th liver m s. The prob b lity s great th t the e y become va c lar t ssue a d hematop ieti h. It ho ld be mph ized that the contribu tio f the mesod rm is most c n p cuou n forms that ha littl or no y lk s c I the ch ck a d th birds, bo h of b h h l rg y lk sa no s ch co trib t n m de The blood i l nd wh h ar the a l g f th scular endothel um nd hema t po ei t ue ccording t th a giobl t con cept, arise i th pla ch ic mes d rm f the yolk sac and re c pi u ly restr cted to th area n the chick It has been a s med that the h mato- poieti t e d l ping t fi st in the blood s- in ds, seeded int th li er from th re and later to the *pleen a d bone marrow a they de vel p* Th r s n d ble ev de e that h seeding occ espec lly from th bl d type f fream rt tw ns in c ttle a d m mmals into h h bon m rrow has be jected foll wi g x x irr d at o In both es the fo e gn ed blood ell type co t e t be produced i d fi nit ly d c t ng th t a e f l tran plantat n f hem t po tic t s e h s oc rred

I those ert b at i wh h the yolk ac is t p l blood lands d ppe on the e tige b t th ghboring spl n h ic mesoderm mak s contr b t t the l r The pla chnic mes d rm at h anteri i t t n l p rt l whe e the l e anl ge ar ses, *s di e tly* c ntin ous by way f th lk s lk th th t of th y lk a wh th bl od l d u ally ari Seemi gly the wh n th y lk a red ced *the* pot t l ty f f rm g g bl t is e t ded to the anteri r testi l portal s ga n. The ll ntr b ted by the pl n h c mesod rm by mese chyme de ed f m t ma dev l p i to h mat p t t ll a ond g t some est g tors It tew rthy th t n f th mes *chym* se ms t dev l p t con ectiv t ss e The c n ect e t ie f the l e arises f m mesen hym th t l t r n ade th l m th th bran h ng p rt l e n nd hepati artery

Structural development Th e de elopment of the ytoarchitecture of th li r a d of the bile drai age sy tem h s been tud ed th oughly in mamm l The anlage of th l r is ord arily s d to devel p i to a m s of ana t mosing cord with th inu oid fo min a netw rk in the space The process of f rm tion was considered to c ns t of a pe etr tion of a larger ein by the co ds in h a way that they become ompletely urrounded by endoth lium This red ces the f rm r cylind cal vessel to a network Th process was named inter cres ence by F T Lewi Th concept of the l er cord has been challenged with conside able just fi cati n by H Elia *si e in the adult the paren* chymal cell ccu in plat s rather than in cords of pairs of ells a is f equently diag mmed H w e er n the chick at l ast a st dy f the early de- el pment of the pa nchyma has led to the c n clu n that the b ic fo m is nde d the c rd w th the pl tes p duc d by wid ning f the co d to form what has been designated a muralium by J Kingsbury rather than a netw rk. I any ase there a e at first n ther bile c p lla i nor bile drain ge sy tem The part f the di erticul *m that* is t form the b le d t end abruptly at the li er mas nd it rows f cell a e ontinuo s with the co d of the parenchyma The li has been likened to oth r gla ds of the dig ti e tra t with the l er c ds equ ale t to th al eolu nd the bil cap lla es to th r l m ns Th patte n of devel pment is howeve quite d ffe ent f *the* d t d e not branch peatedly with a p es mpti e al l s at the end f each branch l t rather the ords them el e br h freely a d ana t m e to form a th ee-dimens nal n tw rk i wh ch em *bl n e of th alveol structu e can be disco e ed* Th e is t this st ge no ind ation of lobul struc tu e u less the whol mass s c d d a gle l bule w th blood ente g through a ein at one end p s ng th gh a v ul r etwork a d lea g by a in at the other

G uth A the m s gr ws t engulfs the port l e n or as n w f equently d th p t l ei pen t ate the m s l ng w th a he th of connec t e t s *The p rt of the d erticul m th t will* lat be m the b l duct ret eat w th th *stump* f the p t l ein nd does n t pe t te th gr w ng ma although it reta its co tin ty with the l e co ds The branches f the b l duct that ac omp y th branches of the portal v n with the l e m e deri ed fr m the *ds of cell* ad jace t t th ein and conne t ve ti ue *Th b le* cap ll s h e ari en app tly beginn ng spo- ad lly *in d fferent places at random i the* s- t m i g network of pare *chym l ell o d t* f rm netwo ks th t continually p nd unt l they become c fl e t, pr ducing *s ngl* c nt uo netw rk

D ct fo mation In th ord n xt t th pe e tr t g p rtal ei a d c necti e tis u th cells ne t to th c t e t s becom flattened a d *th lum n w d* to p oduc the p tur l g g des ibed as the n l f He g The s de f th

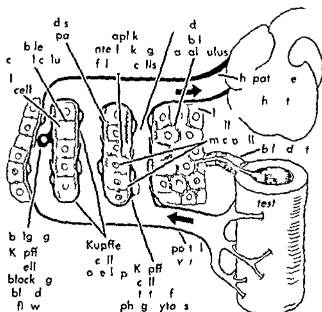


Fig 1 Schemat c d ag am of the liver as a mass of cells (st ppled) based on electron microscop c observa t ons

work of sinusoids The whole parenchyma is di vided into architectural units the lobules A lobule is a thimble haped mass of cells hexagonal in cross section and drained by a central vein which is a radical of the hepatic vein Five or ix portal canals course along the periphery of the lobule Between the cells of the hepatic cords or plates are minute ducts the bile canaliculi that form a continuous network throughout the lobule and at the portal canals drain into the bile ducts carrying the bile ecreted by the cells to the intestine

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The actual form of the liver in the various verte brates and in individual species implies that it is extremely plastic It has been de cribed as a space filling ma s that accommodates itself to the space available This concept is to a certain extent sup ported by the changes in shape that may occur as a growing tumor competes for space or as the hape of the space is changed by tight lacing of a cor et It seems clear that at least from the point of view of function the history of the vessels and the shape of the liver as a whole is quite irrelevant As long as the basic pattern of portal vein sinu oid and hepatic vein per ists the liver functions normally

Classical theory From the point of view of the classical "germ layer theory the liver has three sources of ti sue (1) the parenchyma is entoder mal arising from the floor of the foregut (2) the sinusoid linings and the hematopoietic cells if present are from the angioblast (3) connective tissue particularly in the portal canals is from the me enchyme The surface for the most part is covered by the mesothelium of the peritoneal lin ing In recent years almost every aspect of this point of view has been challenged It has been as serted that new endothelial lining of the sinu oids and po sibly the hematopoietic cells arise in situ from mesenchyme incorporated in the growing liver mass and are thus independent in origin from exi ting vessels or from the blood island and hence independent of anything corresponding to the an gioblast It has also been asserted on the basis of an extensive review of serially sectioned embryos of a large number of species of all clas es of verte brates that a substantial part of the parenchyma itself may be formed from mesenchyme derived from thickenings of the splanchnic mesoderm much as the adrenal cortex and part of the meta nephros are formed The description of cell ori gins from static stained sections may lead to a confu ed and chaotic picture when explanation is difficult and uncertain On the other hand the study of cell origins by experimental techniques has proven difficult

The cell origins of various structures derived from the ectoderm has been extensively tudied in the amphibian and avian egg and the role of inter relations of tis ues in induction beautifully demon strated experimentally Nothing like this eems to have been demonstrated for structures derived from the entoderm It seems that in both amphibians and the chick the e structures are elf differentiating from ery early stages perhaps existing as part of the ba ic pattern of the egg *See* FATE MAPS EM BRYONIC

Role of mesenchyme The question of the con tri ution of the me enchyme to the va cular pattern and even to the parenchymal mass is of a different ort The angioblast concept would derive all endo thelium from the original blood islands by a pro e s of progressi e sprouting Its validity has been repeatedly and emphatically challenged There seems little doubt that after the pattern of blood and lymph ves els is definitely e tabli he l new ve el do ari by sprouting from old one How e er it is definitely a erted that in many parts of

bod and the live is one f the e new ve sel r ance i m se hyme w thout a y n ectı n h already establı hed e sel To this there are ı replies (1) the ema tic que tı n of a defi ı n of mese chym and (2) the ob ervatı n that at is see ı th o igın of a blood ve el is the pearan e f th lumen not the or gın f the cells ı e the c ll of the me nchyme ome f om n ces a d ev ntu lly de elop along pe- lines, the p bility th t they p s ess differe t tencies c n ot be led t It is the efor po l th t end th l um of the blood es ls ı tı ue f om the o t t

Role f mes de m The conc pt of the m sen becomes till mo e imp tant when the con buti of the mesoderm t the dev l pme t of h r n idered There c n b little do bt t, in some rtebrate f rms the splanchnic mod rm, or mesothel m n the vic n ty of th er anl ge pr lif tes and c trib t s cell th t commune with the e dodermal anlage to prod ce the l er m s. The probab lity is great that these cell become a lar ti e and hem t po t It hould be emph zed that the contribu f the me d rm is mo t consp u us in forms th l ba Ltl n y lk I the ch ck and the Lizard both f b h h e l rge y lk acs n ch contrib ti n ı made The bl d ı lands which e th a lag f th a l nd th li m and hema t et ti e cc rd g to the angı blast c n ert, at e s th pla chni mes derm of the yolk sa d r c p usly t ct d t th s a in th ch k It h bee a umed th t the hemato- po e tic de lop g t first ı the bl od is- lands, seeded int the l e f m there nd lat t the spleen a d b m w they de- vel p Th r is o derable e ide ce th t uch seeding occ espec lly f m the blood typ of from rn tw in ttl nd in mammals into h b bo e m rr w ha bee ı jected f ll wing ... ırr d at n. In both cases th f g red blood ll type cont ues to be p d ced ı d fi a l ı d at g that a ce f l t anspl tat them t poı t c tissue h occ rr d

I those teb ates in wh h th yolk s c es- ... blood la d do ppe r the estig b t th ghboring pl n h ı m d rm m kes contribut n t th l er Th splan hn c m d rm at th ant r test nal portal wh e th l ... ge a ses, is d ectly ont nuou by way f the lk talk w th that f the yolk c wh the blo d ı d n lly ar e Seemi gly the wh n th yolk sa ed ed th p te t lity of form g bl t ı xtended t th ant r ı t sti al portal r g n Th cells nt b ted by the pl nch nic mesod rm o by mes hyme de ed f m t may der l p ı t h m top etic t ue ell a co d g t som t gat r It ı n teworthy that f th m ench me em t d l p ı t uncert ti u Th nectı t of th l er mes f m mese chyme th t l te ad th l r mass w th th b a h g p rt l e d h p t c a ery

Structural development The devel pment of the cytoa hit ture f the li r nd of the bile drain ge system has been tud ed th roughly in mammals Th anlage f the li r is ordinarily s id t de elop int a ma s f a ast mosing ords w th the s usoid f rm g a network ı the space The proc ss of formatı n w s consid red to c si t of penetratı n of a l rge eın by th c rds n such a way that they become complet ly s rrounded by end thel um This reduces the f rmer cylindrical ve l to a netwo k This p oces was named inter c escen e by F T Lewis The concept of the l er co d has b en challenged with co side able ju t fi c tion by H Elias nce in the adult the par n hym l cell occ r in plates r ther than in cor l of p rs of cells as ı frequently diag ammed H w eve in the ch ck at least a st dy of the arly de v l pme t of the pare ch ma has led *to the con* lu ion that the ba ic f rm ı ı deed the ord w th the plates produ ed by widening of the cords t form what has been designated a mu alium by J King bury rathe than a network In any c se there are at first neithe bile p llarie *nor a bile* d age y tem The part f th di erticul m that t f m th bile d t ends ab ţ tly at the li er ma s and t row of c lls are tinu with the c d of the pare hyma The li l as been l kened to ther gl nds of the d ge t e tract with th li e rds equi alent to th alveolus nd th b le c p ll s t the r lum ns Th pattern of d l pment is h weve q ite different fo the duct d es not branch peatedly with a p e *umptı e* al lus t the e d f each branch b t ather th ords thems l es b n h fre ly d ana tom e to form a th e-dimen nal n tw rk in wh h n m bl ce of th al e l r tructu e ca be d sco ered There is t this stag no ı d tı n of lobular st *uc* t e nles the wh l mass is cons de ed a le lobule w th blood e te ı g thr ugh a ein at on d p s th ugh a ascul r netw rk a d l ng by a n at the th r

Growth A the ma gr w it engulf the p t l e r as ı w frequently d th portal e pen t te the m l ng with a sheath of c nec t e tissu The p rt f the d vert c l m th t will l ter bec m the b l duct r ı *ts with the* st mp of the p t l ein a d doe t penetrat *the grow* ı g mas ltho gh it etai s ts continuity with th l r co d *The bran hes* of the b l duct that c mpany th bran he of the p rtal n with n th l er m e de ı ed fr m th c ds of ells ad j ent t th n and c n ect e t s The b l apillar h ari app e tly *beginning* spo- adic lly *d ffere t places* t nd m n the na t mo ng twork f pare hym l ll cord to f rm n tw rk that onti u lly expa d u t l they bec me c nfluent, ţ od cı g si gl c tı u u two k

D t f matı n In th e c rd *next to the* p n t t g p rt l e a d nnect e ti the c lls *n xt to the connectı* t ue be ome fl tt ned d the lum n wid ns to produ the p ct e long go des bed th n l of H g The s d of *this*

canal next to the portal vein is of thin pavement like cells and the opposite side is of cuboidal par enchymal cells with the bile capillaries between them emptying into the widened lumen As the con nective tis ue develops it surrounds the cord com pletely and the latter become completely trans formed into a thin walled tube similar to the cholangiole of the adult liver Cholangioles thus developed form a continuous network surrounding the portal vein Only later do more con picuous channels appear in the network with walls thick ened to form the bile duct Although the latter *appear to run parallel to the branches of the vein* they actually till form a much elongated and at tenuated cylindrical network Only at the end where the finer branches follow the terminal branches of the portal vein into the liver ma s do they continue to receive bile capillaries The re mainder of the original thin walled network dimin ishes as the definitive ducts appear and finally eems to disappear entirely for the cell that formed it cannot be identified in the portal canals Finally with the completion of the portal canal the network of parenchymal cell cords adjacent to it widens and fuses to form a continuous limiting plate Where the anlage of the extrahepatic duct come in contact with the new duct formed in the liver ma s the lumens be ome continuous thus establishing the definitive bile drainage system The proces of duct formation within the liver ma s continues a long as the liver continues to grow by the development of new lobules In the rat which has no gallbladder a more exten i e part of the primitive thin walled network becomes converted into ducts than in the mou e which has a gall bladder *It is to be emphasized that in the original de cription of the canal of Hering the subject was* an infant One eeks in vain to find such a structure in the normal adult liver where the bile capillaries empty directly into hort thin walled cholangioles which in turn drain into the terminal branches of the bile ducts

Growth The growth of the liver by the increase in the number of lobules is a process of intussuscep tion The growth occurs throughout the liver ma s *and not by addition to the surface As the mass of* the liver increases so does that of the individual lobule As the lobule increases the portal vein branches and the amount of parenchyma remains constant with re pect to the amount of vein With the production of new canals of Hering and finally of ducts the connective tissue and portal ein pene trate the liver mass as before Corresponding to this new channels appear in the inu oidal net work opposite the portal canal which are con *tinuous with the hepatic vein to form the central* veins of the new lobules The lobules of the li er are remarkably constant in ize throughout and re main constant as the liver grows The terminal branches of the portal veins are equidistant from the central veins throughout This relationship is considered to be developed and maintained by hemodynamic action according to a theory de el oped by K Thoma and applied to the liver by F P Mall

Thus in the development of the cytoarchitecture of the liver the bile capillari s em to ari e au *tonomously in the liver cords the bile ducts by an* inductive action of the portal connective tis ue and the lobular pattern by hemodynamic action as the mass increases [J W WI]

ANATOMY

Human anatomy Both function and structure of the liver can be understood only if one knows how *this organ is as ociated with the blood stream* and the intestine Both histologically and anatomically the human liver is one of the simplest of vertebrate livers and is u ed here as a model for the vertebrate liver

Blood supply The blood which treams through the spleen and through the capillary bed of the stomach and intestine is collected by veins whi h converge into a wide but short ve el known as the portal vein This ves el enters the liver through the porta hepatis or the door of the liver whence

Fig 2 Sch mat d ag am of huma l v r and t m lor dor al conn ct on R m e a p rtae C c nt al I ntermed s ID infe o de te Inf f or s n te L lateral Q q ad atu SS up r o s t V n e hep t ae HCD dor ocaudal HD dext a HM m d a HS si ister

th ram portal n This do r of the li e a broad dep es in th infe r pot r or d r o ca dal rfa e of th org

Th port l ei e a portae comm branches the porta h p t i t a hort ht trunk the tra ca d ter d i to a l g left trunk the tra cus te From th ari e two t u ks branches or ram h ch p etrate deep t the bst f the l r a d bra ch e te ly The e intrahepat port l e n branches f m th ores ftun l alled p rt l c l

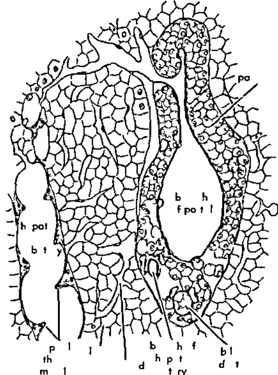
Th h uppl ed w th e bl d which is rich ur hm t by mea s of the portal vein Th eno blood of the p tal n is uppl men ed b arter l blood wh h i b ght t the liver b th hep t artery elat ely thin essel h h ses f om th celiac arte y d by n oc ca l es ory hepat tery The hep t ar tery enter th li e th ough the p t hepatis Its b h r n l de th e of th po t l ein within th portal al Oft there are tw more hep t art ry b an hes i p tal canal These ll a t ri ar con cted w th an other b t m Th b an h f the p rt l and f the h p t c artery mpty i t th ee d en l net rk of spe lized pillarie th so-c lled l er d Th i d i t di h g th blood i t trib t re f the h p tic ven h h c u e w thi the called hepat l The l g t hepat e ns mpty t the tra fe o

C al s t ms The po t l nd hepat can l r th st m of t n el e t ly dep dent f ach her The p rpe d c l rly nd epa rated b i t rv g l e pa en hyma a d s d

Th ind d l b ches f the p rtal nal t h t n th po t l e a d h pat rterie er n t m ith th e ghb that h bra ch f the e es ls h ts wn h rply de fi ted terr t ry h h it pple Th d n f d g t rr to es of nd d l h pat c e nt ib ta es eq lly h rp S g o m t be wa f th l k f t e n t e the a t m s ll t al If ne b a ch of th e essel is lig ed, its e t e t r t rv f pply o d a ge d generates Y t, becau e f the perp d l d eta li g f port l a d hep t c l th hum n liver u fied It s u t r pt d n twork of an ds, th p e b t ee whi h a e filled w th l er ll

Bl d t A y tem f bile d t r fr m e t ble p lla e a l c l betw n the l er ll Th b l d t ru n the port l al but they d t th i nte t i a d r t op- po t th i f th blood fl w I th med m ed d th l g portal al tw m r b l d ts d d th gle b h f th p rtal e Th ed t a t m e w th the ghb s i th a port l ca l

The b l d t f m all th port l ca l co erg u f rm th hepat d ct r d tu hep t us m th port h pat Th d t h s l g o t



Fg 3 L f th p

pouch g the gallbl dde o ca f ll wh ch h s hap m lar t th t of el ted p Its t lk d t y ticu the y ti d t Bey d the j ction f the h p ti d y t duct the d t y tem co t de the n me f th e mm n bile d t or d ctus h led ch nd fi lly empt e t th duode um r pp p t n f th m ll i t t e S GALLBLADDER

Comparative anatomy I e tebr t ther s o k wn org which i htly be lled a l er O the the h d ll ert b te po l r It p rh p be a of t h m ge o mple t uct th t th l e h n t e lly hape f t w It a pl t c m that fills o t p e m ng the th org i th abdom l c vity T w d the b dy w ll the l e co ex Wh e t i t ct w th th o gan th e g m k im p t

L ho d t Th stom h ep thel m f the A d a p e flat o tpo ket g wh h p jet t th b d its Bec u e th blood p- ply a d d i g of the lamell e n t u de t d t s imp sibl t est bl h wh th the e d ble h et f cell may b h mol g to l er ll pl te

I *Amph ox* the st bl nd tp cket g f th f r g t wh ch id ed by m ny t be h m l of the l e

I t b at I the gr p P c th fi he the l f b th C l tom ta d Myx f rm s c s t f a cra l a d ca d l l b n eted b n thm I th mm o tes I rva f l mp eys P t m o t f me the l e n i t f two l g l ft d ght l b wh ch r e t d b a thi

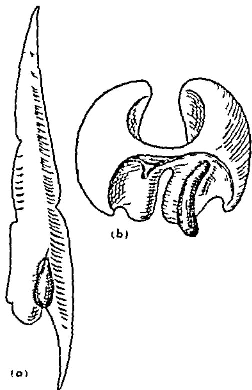


Fig 4 (a) Dorsal aspect of l er of Amph sbaena dar w n a l zard (Rev museo argent no c e c nat 3 165 1957) (b) Liver of All gator m ss ssipiens s

helf During metamorphosis the liver lo e its duct system and shrinks to form a ringlike mass behind the pharynx Among the Selachii the liver is hor eshoe haped and the free ends point caudad It has a very high fat content The shape of the liver in the Teleo tei undergoe many variations In many teleost and ganoid specie the pancreas is located within the portal canals

The liver of the caecilians Apoda is divided into numerous lobes which cover each other in a shin gl like fashion They are all connected by a narrow longitudinal bridge The liver of salamanders and newts Caudata is lobated in ome species and uni fi d in others The liver of the frogs and toads Salientia consists of two large lateral lobes con nected by a broad median portion The liver of the amphibians receives venous blood not only through the portal vein but also from the lower extremi ties through the abdominal vein

The unified liver of snake Serpentes and liz ards Sauria is adapted to the shape of the body The liver of turtle Chelonia and crocodiles Crocodilia consists of a right and a left portion connected by a narrow isthmus

The liver of birds is a rather unified bilobed organ

Among the mammals with unified livers are the Ruminantia the Cetacea and ome Hominoidea such as man the orangutan chimpanzee and gib bon but the gorilla has a lobated liver The livers of all other mammals the anatomy of which has been recorded are lobated

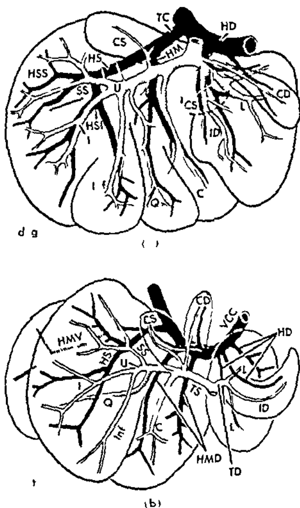
In unified livers the hepatic veins run at almost right angles to the portal canals but in lobated livers with deep incisions between lobe the large hepatic veins run parallel to the large portal ca nals and crossing occurs only among the smaller ves els In lobated livers partial hepatectomy is easy but surgery on unified livers is very difficult

Among mammals there is a remarkable uniform ity in the pattern of branching of the portal and hepatic canals In spite of differences in external lobation the only basic variation in the vascular pattern is the location of th bifurcation of the common portal vein relative to the origin of the ramus centralis

HISTOLOGY

The structure of this organ of multiple function is remarkably uniform throughout the phylum of the vertebrates

General morphology The liver of all vertebrates, with the exception of adult Petromyzonidae is a



F g 5 (a) Do s l aspect of l ve of dog (b) L ver of at Ram ve ae portae C c t al s I inte med us ID infer o de ter Inf infe io s te L late al s Q quad atus SS s pe r s n st V ae hep t c e HD d xt a HM med a HMV v nt al di on of me- d a HMD do sal d s o of med a HS ist r HSI s n t ae rad Inf o HSS t ae rad s pe Ramuli CD caudatu d ter CS caud t nt te TC t un us commun T u enae port e TD de ter TS s nt t U pars mb l cal VCC v na ca a in f or

n..ralium, that is a ystem f c nected wall Th term l um implies that the l e e embl nst b ildi g n ts t t re with m ny blong ften cylind c l li htly cro k d room the la nunae h patis. Ne ghb g l nae a e parated from e an th r by w ll built of l ve o h patic cells. Thes wall also called l r plates o l m nae hep ti ll connected w th each othe and form a h ghly b an hed d ne er ending c b dal epithelium They a porti ns of the un nt rrupted n..ralium. As th ro ms in a buildi g e ted through doors d ghb g l nae com m..ni t th each other thr gh pen gs in the liver pl tes in h w y that the lacunae hepat s together f rm a t a d u inte upted sy tem f con ected t nel the l byr nth hepat

Canal y tem Th l is pervaded by two sys tem of wid cyli drical t n l th po t l canals and th h pati canal which rve s commun cating struct es within the li er Th e tw nal syste s d etail w th o ther but always remai sepa ated fr m ea h other by d st nce of at least 400 m cr ns (μ) E ch canal y t m is h ghly bra h d but there e n s connection between b a ches e of the sam l Th bra h g of a h nal sy t m r mble th t f tree.

I ost c s, the b ch g of th port l nal system app o m t s th d h tom u pattern herea th hep t c l ystem tend t w d a mon podi l pattern

Limiti g plat E h po t l d h p tic l is lined b gle l ye f l ll th l mit g plate. The nti e rg n als lim ted t w d ts surf ce, by a e t r al l mit g plat

All th l mit g pl t s th e tern l the p port l h h s rr d the p rt l l d the perih p ti u r u d g th h pat c ls e u w th e ch th r a d w th the t rnal

Fig. 6. Sch at diag m f th ll l truct f the liver

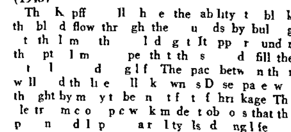
Fg 7 S h m t d g m f p rt l l w th d g l t

mural m Th periportal and perihepat l m t ng pl tes have nume ous mall ope ing th t the l c mmu cate p ofu ely with the labyri th f l u e H we e neithe the canals n the la nae ar mpty t m ght appea from this de c iption A three d men l tw k of p l ed p ll s the sinusoids i u pe ded in the l byr th f l d co nect d th ugh the pe fo ations n the l m t g pl tes w th the bl d l n b th can l systems

The e t r l u und d by a fib us p ule e ed at most pla by pe itone l m so-thel m Th n t e t e of th fib ous p-l efle t d int th nte r of b th ca l system nd ries blood e l duct lymph l nd nerv d p t the org

Cellular morphology Th l t ss e com p ed f tw k d f ll th h p t lls l (par n hym l) cells a d th K pff cell

Kupff ll The e ll e th pe l d et ul nd thelial ll whi h l n the nus ds Alth gh cell b nd es can b dem tr t d by th l e tr t m thod in mm n d thel m thi is n t p ble in th e of th l n g f th l e t so d Hen t w bel ev d th t th i u o d w ll w s of a yn yt l h a t H weve l t n m o p tud e n 1957 ev l d the d du lity f th ell They ha lloped m g s nd l p Th K pff cell r p t t l ph g cyte The n mb of Kupffe cell a ti ph g cytes d p ds n the ds f th m me t d g t M K ely E Bl h and L Warn (1948)



Th K pff ll h e the ab lity t bl k th bl d flow thr gh the u ds by bul g t th l m th l d g t It pp r und r th pt l m pe th t th s d fill the t l d g l f The pac betw n th r w ll d th li e ll k wn s D se pa e w th ght by m y t be n t f t f hri kage Th le tr m c o p c w k m de t ob o s that th p n d l p ar l ty ls d ng l fe

Liver cells or hepatic cells These are the components of the hepatic muralium The shape and volume of each hepatic cell depend on its location in the muralium A cell touching a hole in a liver plate the smallest type may have the shape of a pentahedron with an approximate volume of 10 000 μ^3 whereas the cell which is located at the junction of three laminae the largest type may have an approximate volume of 35 000 μ^3

The nucleus of the liver cell is spherical and contains a large nucleolus Some nucleoli are basophilic and others are acidophilic Small liver cells 10 000 20 000 μ *have one nucleus each but larger* liver cells may have two or three nuclei The liver cells contain piles of electron micro copically demonstrable double membranes the endoplasmic *reticulum and spherical to rod shaped mitochondria* with internal double membrane The liver cells are fastened to each other by club shaped projections of cytoplasm of one liver cell which fit into depressions of the adjacent liver cell in the manner of snaps Another mechanism of holding the liver cells together is provided by the polygonal network of bile capillaries the canaliculi Each mesh of this network surrounds a liver cell Because the walls of the bile canaliculi are tough this network gives the muralium a strong support *The walls of the bile canaliculi are condensations* of exoplasm of the hepatic cells and it appears in electron micrograms that through the walls of the bile canaliculi adjacent liver cells are continuous with each other Microvilli project into the lumen of the bile canaliculi

The facets of the liver cells in contact with lacunae is studded with short microvilli The space between these microvilli is the perisinusoidal space of Disse

Comparative histology Most lower vertebrates have laminae hepatis predominantly two cells thick the muralium duplex but the mammals and the songbird Passeriformes as well as a few lower birds have liver cell plates one cell thick the muralium simplex In Amphibia there is a mixture of muralium duplex and muralium simplex The latter is predominant in amphibian larvae

Minute vascularization The portal venous blood enters into the network of sinusoids through short side branches the inlet venules of small portal vein branches The inlet venules pierce the limiting plate

In man *the smaller branches or axial distribution* veins of the portal vein which are 280 μ or less in diameter give rise to inlet venules all along their course The larger rami or conducting veins 400 μ and thicker do not give *rise to inlet venules* The tissue surrounding them however is very well vascularized by side branches the marginal distributing veins which run parallel to the large veins or surround them spirally These give rise along their course to inlet venules

In the rat the large portal vein rami do not give rise to inlet venules and only rarely to marginal distributing veins so that the tissue surrounding large portal canals is poorly vascularized All portal vein branches in the mouse give rise to inlet venules as a result all periportal areas are well vascularized

In man the sinusoids enter the smallest tributaries of the hepatic or central veins only whereas in the rat and mouse sinusoids enter the hepatic veins of every caliber

Thus the livers of both man and the *mouse are* well supplied with portal blood and the liver of the rat possesses areas poorly supplied with portal blood On the other hand the liver of the rat and *mouse are well and evenly drained whereas the* drainage of human liver tissue must go through the narrow bottlenecks of the junctions of central veins with sublobular veins

The hepatic veins of the dog seal carp and a few other species are surrounded by spiral muscles which can contract on histamine stimulation These throttle muscles play a role in anaphylactic shock In most animals there are no such muscles

The hepatic arteries give rise to capillary networks around the bile duct The venous blood from these periductal networks drains into portal inlet venules Other and more important terminations of the hepatic arteries pierce the limiting plate and penetrate to various depths in the liver *tissue They open into sinusoids at all levels be*tween the portal and hepatic canals

Lymphatics Tissue fluid flows from the spaces of Disse into a tissue space at the periphery of the portal canal From there *it must filter through the* connective tissue of the portal canals and through the endothelium of the lymph vessels which are present in great abundance in the portal canal

*In the dog in addition to periportal lymph ves*sels there is a vast lymphatic plexus around the hepatic veins

It is obvious that these specific differences in vascularization render the application to man of experimental results obtained in animals somewhat problematic

Lobules Under normal conditions the sinusoids run radially toward the small tributaries of the hepatic vein This pattern gives the liver the appearance of lobulation The center of a hepatic *lobule is occupied by a central vein the smallest* hepatic vein The portal canals appear between the lobules and the smaller portal vein branches are sometimes called interlobular veins The lo*bulation of the liver is however only an expression* of the portohepatic blood pressure gradient for when the blood pressure in the hepatic vein is elevated or that in the portal vein lowered as may *happen in diseases such as heart failure and tu*mors the lobular pattern is reversed When it is done experimentally by ligation the lobular reversal occurs in 2 minutes In these cases the sinu*soids radiate from the portal canals which appear* *now as centers of lobules In the pig* raccoon and polar bear liver cells along planes connecting neighboring portal canals begin to degenerate about a year after birth *In these planes connective ti*

septa devel p hich gi e the l e f the e l a perma ntly l bul ted ch racte Th n h been inte p eted a a pur ly portal nd th ef b l al h S e CIRRHOSIS LIZED TI UE (BIOCHEMISTRY)

PHYSIOLOGY

the ma y f ctio of the l e the p i ppear t be th t of t ge d ilati n of food Th co ept is ggested by the devel ping l t the all rteb tes a d by the d ect tra n of the y lk i t the l er wh ch oc amph b s

Food storage and use Y lk t ed food de p ited m th g f by th g ow g emb y l amphib n blood l d i e w th the m lk cell Th blood s l nds coale c nd be th d fin ti l er n o d a d the yolk d m l c ll betwee th m b m th l er ll

the t m the yolk i c sumed the tad gl begi t t Hen ef th th p tal e com the i te t e d on e t d with the l er d bring th e ly d e t d fo d f m the t mt the f rme y lk a n w all d li e co d r ble m nt of t s tored t b the g m eed it

F d t ed i the l er cells h fly in the f m f th pl c h ide gly g n a d i th f rm of L Gl co e th d by th l e c lls f m fru t e d gal ct Th p n eat c i ln i ilt te th s pr e b t it fat n n t yet u d r t d Gly gen c be the ed by the l ell f m f tt d a d l t ac d The ti f p rt la ly mp rta t d i g t rv gy i p od ced thr gh ut th b dy d t n f gl c s T a gr te te t d ed f m the b e kdown f h pat c d th infl e of th othe p n h rm n gl c g n

F t ed n the l e nd y the d f m wh n a ex e f th l tt Th p oces m y le d t f tty d g e f th l hi h m y be f ll w d by ho-

The l m nt by the st ag of f od t ff f gl lm st c n t t gar 1°0 mg/100 ml f bl d part l ly bl d pla m o e prod d by the l e ell a well l n f th t ol wh ch o nm l f t d l V t m A D d a d ca t es t r d h fly n th

Th l cell r t a g ee b tt lled b l t the b le a l c l Th e b les mmu t th ugh m ll d h l g les w th d t whi h d s h rge zh th mm n b l d ct nt tl A pr l m v t g pl f th g llbl dd Tl l m p tl m of the gallbl dder s pr ided with a tr ated b der n isti g of m cro ll It i s m d that the e m o illi re t m ntal i eab ptio f water f m the bile thu i c ea g the nce t a t on f the bile It has been p ed that th gall bladde is t ne e ary for l fe by the f t that ome nim l f r example the hor do t po ses gallbladd r Al o s gi al em l f the gallbladde ch lecy tectomy i t ha mful

An mpo tant comp nent f b le the bil ac ds e f med b th li e ell The re e ent l f r the ab o pt n by the i te t l ll of f t l pid d it mi A a d D for they mul ify and make them m scibl w th wat and thu cce bl t the d ge ti e act n f lip es p d ed by th p cre and by the inte t al glands It al o umed by me that the b le a ds a ti at th pan eat c l pa e

Bile pigments (b l rub n a d bili erd) ar cat b li p od cts f h mogl b n They r pr duced m nly by ph g yte n th spl en d b n ma ow wh h h e ge t d y th cyt The li ell em e the e p gm nt f om th bl d st eam a d tr sp rt them nto the b le ca ali li The bil ls co t in ch le te l p d ed p rt by l er ell nd e bs rbed l ter b the i te t e Oth end pr du ts of met bol m d rta n h t n rtific ally i t od c d i t the blood tr m a e eted by the l e ell i t th bil

The l er ll ma f t a ema kable b l ty to tr n po t ub t n ag i t an o mot c p e su e g ad e t s that th c e t at n f the ub- t c in the bil m lt pl of the n nt t o n the bl d Th s bil ty h bee att but d t the el tr m op cally d m nst bl do ble memb a s

Detox fi t Many p i o bst n e a e det fi d i th l r by d r dat id t nd c j g t Ho m e p rt c l rl e h m e d tr yed b the l e a m la m n er Th s p pe bal f the h mo s ma ta ed the b d The Kupff ell ar th ht t pl y n mp ta t r le n th p ce The c lls l o m e p rt c l i m ti f m th blo d by th phag cyt ct ity *S* HEPATITIS LIVER DISORDERS [M H E]

B bl aphy L. B lk E Go pp rt E K ll d W L b h *H db h d l gl ch d n A t m d W belt e* l 3 1937 H El Li m rph l gy *B l Re* 30(3) 263–310 1955 H P ppe d F S h ff r *L i St u t a d F t n* 1957

Liver disorders

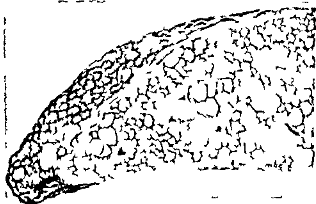
D d f th l a f p rt c l mp tan e be u f th m ny e ti l phy l g l f n t f th l g g Th l r i tim t l ned w th the met b l m f p te fat d b h d t d w th th m l de t fi t n f m y h m es d ma j m t b l w te prod t Th l ec b ut 25% of ll f th bl od p mped t f m the h art

including all of the blood draining from the intestine *See* LIVER

Cirrhosis Cirrho is is the term applied to the end tage of carring of the liver *It may follow re*peated minor insults or a single sudden ma sive injury The more common causes are nutritional deficiency as shown in the illu tration (Laennec or portal cirrhosis) viral infection and injury by chemical agents (po tnecrotic cirrhosis) ob truction of the drainage of bile from the liver (biliary cirrhosis) and prolonged and severe heart failure (congestive or cardiac cirrhosis) Since the u e of antibiotics syphilis has become relatively uncommon as a cau e of cirrhosi at least in tho e regions where antisyphilitic therapy is available Because the liver has a large functional re erve minor degrees of cirrhosis may have little phy iological effect More severe instances of the di ease however lead to early death

Malnutrition Nutritional di ease of the liver is een particularly after prolonged and exce ive u e of alcoholic beverages but may occur a a result of malnutrition from any cau e and may even develop spontaneously in animals The dietary deficiency is not a lack of sufficient calories but an inadequacy of a few e sential foodstuffs particularly the amino acid choline Under the e conditions mas ive amounts of fat first accumulate in the liver cells enlarging the cells and th liver itself Such large fatty livers may have impaired function and are unduly susceptible to further injury from many toxic agents to which the liver *may be exposed Sudden unexplained death of* many liver cells may occur at this fatty stage lowering the function of the organ below the level essential for life of the individual More often the di ease progres es insidiously and persi tently with the development of fibrous scarring and with disorganized regeneration of liver tissue

After a period of many months or years the entire architectural pattern of the liver is distorted



Portal (Laennec s) cirrhos s of the l er The normal uniform a chitectural pattern has been dest oyed and replaced by l rge and small nodules of egenerated l er tissue sepa ated by bands and septa of connec t e t ssue This is the edge of a large sl ce remo d from the l er

and replaced by small and large nodules of d organized liver cells eparated by bands or ep of connective tissue With this progres ive fibro *and distortion there al o occur ignificant chang* in the small blood ve s ls in the liver seriou ly a tering its blood supply The small veins draini blood from the liver become narrowed and t flow of blood *through the liver is impeded Behi* this ob truction pressure ri es in the portal vei which carry the blood from the gastrointe tin tract to the liver and new channels develop carry the blood around rather than through t liver Particularly important among the e latt channels are veins beneath the muco a of the e op agus (varices) which may become eroded and t the ource of ma sive hemorrhage In late stag of the disea e the amount of blood reaching liv cells may be in ufficient to maintain the bare t e sential function The patient then dies in hepat failure with alterations in the blood protein a cumulation of fluid in the body cavities and th accumulation in the blood of toxic metabolic prod ucts such as ammonia *See* MALNUTRITION METABOLIC DISORDERS

Viral infections Viral hepatitis the most impo tant infectious di ease of the liver may be cau e by either of two closely related viruses The e tw agents produce identical changes in the liver bu *differ in their mode of spread and in the laten* period between the invasion of the ho t and th manifestation of di ease In one ca e the orga i ms are acquired by the oral route (infected foo *or water) In the other case they are acquired b* the injection of erum from a patient with the dis ease or carrying the irus The former di ease i called infectious hepatitis the latter homologou serum hepatitis Jaundice is the striking clinica feature of viral hepatitis although other symptom such as malaise abdominal pain and loss of appe tite may also be distre ing The effects of the viru on the liver are characterized by injury and deat (necrosis) of i olated liver cells or groups of live cells and by an accumulation throughout the live of large numbers of mononuclear white blood cells Drainage of bile through the tiniest bile channels the canaliculi is impaired *and bile accumulates* there and in the li er cell them elves In the more evere case necro is of liver cells may be o widespread that death of the patient occurs early in *th illne U ually however complete* healing occur after a few week with no re idual altera tion in the tructure or functi n of the organ In a fe v instances when the di ea e is protracted in its course or is a ociated with evere but nonfatal necr i postnecrotic cirrh is may result The architecture is then di torted by wide bands of con necti e ti sue and large bizarre nodules of reg n erated liver ti sue This postnecrotic cirrho is is al o as ociated with a cular of truction *and its* complication just as is the portal cirrhosi of nu tritional li er disease *See* JAUNDICE

Yellow fe er is another virus di ease affecting *the li er It is spread by certain mo quitoes* and

including all of the blood draining from the intestine See LIVER

Cirrhosis Cirrho is is the term applied to the end tage of carring of the liver It may follow repeated minor in ults or a single sudden massive injury The more common causes are nutritional deficiency as shown in the illustration (Laennec s or portal cirrhosis) viral infections and injury by chemical agents (po tnecrotic cirrhosis) obstruction of the drainage of bile from the liver (biliary cirrhosis) and prolonged and severe heart failure (congestive or cardiac cirrho is) Since the use of antibiotic syphilis has become relatively uncommon as a cau e of cirrhosis at least in tho e regions where antisyphilitic therapy is available Because the liver has a large functional reserve minor degrees of cirrhosis may have little physiological effect More evere instances of the disea e however lead to early death

Malnutrition Nutritional dı ease of the liver is seen particularly after prolonged and excessive use of alcoholic beverages but may occur as a result of malnutrition from any cause and may even develop pontaneously in animals The dietary deficiency is not a lack of sufficient calories but an inadequacy of a few essential foodstuff particularly the amino acid choline Under the e conditions massive amounts of fat fir t accumulate in the liver cells enlarging the cells and the liver itself Such large fatty livers may have impaired function and are unduly susceptible to further injury from many toxic agents to which the liver may be exposed Sudden unexplained death of many liver cells may occur at this fatty stage lowering the function of the organ below the level essential for life of the individual More often the dı ea e progres es insidiously and persi tently with the development of fibrous scarring and with disorganized regeneration of liver tissue

After a period of many months or years the entire architectural pattern of the liver is distorted

Po tal (Laennec s) cirrhosis of the l ver The normal u i form a chitectu al p tter has been destroyed and eplaced by la ge a d small nodules of rege erated l ver t ssue separated by b nds and septa of connec tive t ssue This s the edge of a large slic remo d from the l ver

and replaced by small and large nodules of disorganized liver cells eparated by bands or septa of connective tis ue With this progressive fibrosis and distortion there al o occur significant changes in the small blood vessels in the liver seriously altering its blood supply The mall veins draining blood from the liver become narrowed and the flow of blood through the liver is impeded Behind this obstruction pressure ri es in the portal veins which carry the blood from the gastrointestinal tract to the liver and new channels develop to carry the blood around rather than through the liver Particularly important among the e latter channels are veins beneath the muco a of the e ophagus (varices) which may become eroded and be the source of ma sive hemorrhage In late stages of the disea e the amount of blood reaching liver cells may be insufficient to maintain the bare t essential function The patient then dies in hepatic failure with alterations in the blood protein accumulation of fluid in the body cavities and the accumulation in the blood of toxic metabolic products such as ammonia See MALNUTRITION METABOLIC DISORDERS

Viral infections Viral hepatitis the most important infectious disease of the liver may be caused by either of two clo ely related viruses These two agents produce identical changes in the liver but differ in their mode of spread and in the latent period between the invasion of the host and the manifestation of disease In one case the organisms are acquired by the oral route (infected food or water) In the other case they are acquired by the injection of serum from a patient with the disease or carrying the virus The former dı ease is called infectious hepatitis the latter homologous serum hepatiti Jaundice is the striking clinical feature of viral hepatitis although other symptoms such as malaise abdominal pain and los of appetite may also be distressing The effects of the virus on the liver are characterized by injury and death (necrosis) of i olated li er cells or groups of liver cells and by an accumulation throughout the liver of large numbers of mononuclear white blood cells Drainage of bile through the tiniest bile channel the canaliculi is impaired and bile accumulates there and in the liver cells them el es In the more evere cases necrosis of liver cells may be o widespread that death of the patient occurs early in the illness Usually however complete healing occurs after a few week with no re idual alteration in the structure or function of the organ In a few instances when the disease is protracted in its course or is associated with severe but nonfatal necrosis postnecrotic cirrhosis may result The architecture is then dı torted by wide bands of connecti e tissue and large bizarre nodules of regenerated li er tissue This postnecrotic cirrhosis is al o associated with vascular obstruction and its complication ju t as is the portal cirrhosis of nutritional liver disease See JAUNDICE

Yellow fever is another virus dı ease affecting the li er It is spread by certain mosquitoes and

geographi ally estri ted t Afri a d t South and Central Ameri a, he e in re ognized and un ecognized f rm it rel t ely omm n J nd ce resulting fr m the nec of li er ell s e po s b f r its ame. H p titi of iral ti l gy oc curs in d g and in p gs, and it is possible th t the lat r d ease, po ci e h pat ti is cau ed by th same irus that is respon ble f infect us hep titis in h m In South Afric an bs ure fatal disease f h se c lled tagge s mal nelte, a sociated ith ev re ec is f the liver and m y also be f vi l origin *See* YELLOW FEVER.

Bacterial infections Bacterial infect ons of the liver are ften seco d ry t nf ct on primary other tes Infe t m y p ad fr m the g ll bladder up to the mall bile d ts w thin the liver prod cing fl mm t th e (holangioli ti) I fect ns in the t tin l tract, part ularly *ye d tis, m y p ead to the li r th gh the* portal ein. Absce ses ar the us l co equen of this so-called pylephleb tis Alm t any gene alized *lection f th body may in ol e the li e eco d* ril and in some such as typh d feve bruc llo-sis, and tul em a, th the rule In lept piro-sis, the pirochetes espo bl f r th di e produc li er jury and jaundic well as d m age t *other rgans Dog and ther nimals are* fre ently fected by these ame d imila r pattern *See* BRUCELLOSIS TULAREMIA TYPHOID FEVER.

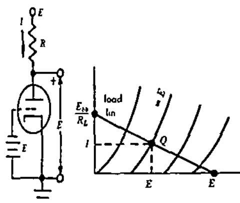
Parasites. Paras t c infections in ol e the li er f a s d animal *Am b c b es e of the li* are the mo t commo a d mo t seri ompli ns f the int tinal fection by this p ot zo n Am b li er abscesses are u ually gle and may bec me ry large. They m y bec me eco d rily ected with b ct *ria, r may ruptu e int th* pleur l, peri ard al, or peritoneal a ities nd t the l g bo el. The t y blood fl ke known as sch tosomes in de th ki f d d ual bathi g in i fected tr pical w t Th y ev n tually find th r ay t *the m ll blood e l* the liver her they mat e d where they c u hr nic infl mmat and ev t lly asc lar ob-structi n. Other paras ti dise ses of the l e are more comm n mals, b t man is ft i ected incidentally The *l r l stage f th d g* tapew rm, *E hi us g anul us* h p ed lec tio f th l th i t rm d te h t wh h include man, heep cattle d man th mals. l the l r the. p it prod l rg cy s, u lly w th th k l fied w lls Oth m portant para. t s fe ti g the l of man nd l e th l fl ke wh ch h b t and ob-struct the m ll b l d t Thes pec fi b t rial. L nd par t d se se a e d sc ed d t l wh r d the app pri t h ad gs. *S* the ar s.

Chemical agents T h p t t the type f l er injury ed by h m al g t g ted r inhaled nt th body Th e e m y compo d led hepat t s, wh h r p bl f dam g ing the li e The m t mportant a e chlor form a bon t tr hl ride, ph ph rus, and the poison f th mushroom *Am nit phalloides* They p oduce f tty ccumul ti n d necro s *in li r c lls ften* w th a di t ncti e patt rn Becau e the li er has great powers f ge erat n omplete he l ng witho t esid al effects may foll w mod ately e e toxic inj ry If t o ev re however such in ults m y be rap dly f tal or m y be foll wed by the development f p tnecrot cirrho i Ma y drugs may be injurio to the l er in susceptible or sen iti indi duals. F rtunat ly drug injurie are not often sever enough to be f tal and a rarely f llowed by c rrhos

Obstruction Bili ry cirrhos s is the end esult f pr lo ged ob truct n t the drainag of bile from the li r B hind th ob truction, the b le du ts be-c me gre tly dil ted. B le accumulates there in the tiny canaliculi, and w thin the li r cells them sel es. *Bacterial inf ction f the bile duct s* freq t complicat and is ften re urrent E en tu lly ext n i e c nnecti e tissue p liferati n re ults, and li er fun tion p gre si ely fails Impa ti n of gallst e n the common b le duct may precip tate u h a p ocess and tumors of th com mon b le duct or pancreas are lso common cau es Bil ary at esia, o failure f th bile du ts t de-*elop in the embryo h s the ame consequ ce* unles urgically c rrectible t leads to b l ary cir h is nd death in infancy or early childhood

Other diseases Ther are se eral obscure dis-es which m y i ol e the li r al ng with other *rgan In amyloidos the peculia chemic l de-*pos ts charact ri ti of this di ease are l d d wn in the li r a well a in c rta n ther tis es. Th bscur chro infl mmatory disease called sar coido is mmonly in l es th li e W lson *di ea o hep t l tic lar* degeneration, is ra diso d f coppe met boli m in which the e oc urs cirrh f the li er along with severe dam ge t the central erv us y tem Hemochromatosis d so d f ir n metabol m, is ch r t rized b excess e a um l t of ir in the li er d ther ti es and by the development of eve and ft n fatal cirrho is I prol ged ec rr nt h rt f l r ffi t l d m ge may be pro-d ed so th t nnect e tis ue scarring oc urs (o g t di c cirrho is) This is of minor s gn ficance compared t th effects f the maj card c disease

Tumors. Tumor of the n nmalign t type e are in the li er e pt f the neopla m f blood es el *called hem gi m s* Th se s w ll a les c mm ben gn tum rs of th li er e lly m ll and f l ttl gn fican e M l gn t t mo s f th li r appe t be i r a i g freque cy Th e n t am ble to rgi l tr tm t d e p dl f t l S h tum s ally arise f m th l ell themsel es (h p t mas) r f om th b l d t with th l e (h langiom s) They are p rt l ly comm in l s with portal r po tne r t rrh d hemochr mat s They h l ttle t *d cy to p d* tsid the li b t



Load line d n pl te-c rr t h ct t cs

tion l t g pl te urre t to plate olt ge a d grid lt ge is t k w a lyt lly A et of pla curre t rves w th load li d aw s l l strated. S e VACUU I TUB

W the t be h fi d b the p c d re for d g the l d l e s impl The l d l d at t sect the plate- lt ge is t a lu equal t E_{bb}, th pl te pply ltage d th load a t al f plat r nt whi h is eq l to E R he e R_L s th l d re t ce The quiescent pl te urr t I and plate lt g E_b ad at the p t Q wh e the c rve fo th alue of grid b as int r t th l ad l ne

If the t be lf b d by c th de e t the load lin d n by th pr ed r te f ll p ctic l p po e f the ltage d p ac the athode r t r i nl a few per e t f th p' lt g (whi h s ally tr e) How the grid b m t the be d term ned by t l d error

L d l es re l u d with t a t c ts and oth n nl n r de i to det m n th q nt po t. [H F K]

Loading electrical

The dd t f du t e t t m n l n n der to mp t tra m n h t t c er th eq ed fr q cy b nd Load g c l ften nserted n t l ph e l t p g a lo e a l m le, t u te a t th ap ta e f the l nd th m ke the l mped ce m r load q l t t a p t e S m la h ar sed bet een t n f l d f an tr m S TRA I SION LI E

W h l bl s d a g des l d g i ed t th d f th l t bsorb ll p h g th nd, the eby a hie g n n flect ng t Th l y ect u d f th p r line m y be tapered m t l es wedg f l dielect ic m i l t pe ed ect f r d t f the l e S W VE UID

When t t loo h rt t g at be des d f l y l n b rted i hich the t n t g th req ed m t

of l ding ne ded for r onance A an example p ct cally ll to rad ha e load ng coil n th nt nna c t b cau e the us al whip antenna i much t h rt f r b adca t band freq e c s S ANTENNA (AERIAL) [J MR]

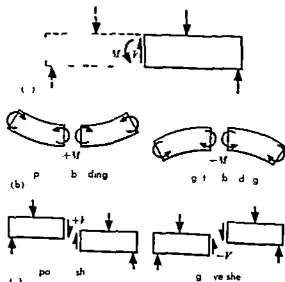
Loading transverse

F ces appl d perp dicul ly to the l ngitud n l axis of a member Tran er load g cau e the m mber t bend a d defle t f m it ginal p i t with nte nal t ile a d compres i e t ai s ac mpany g chang n cur t re

Co cent ted loads ar ppli d o er a eas le gths wh h a e elati ely small c mp red to the d men o f the memb A gle r ult t fo ce u ed t an lyze eff ts n the m mb r E mpl s are hea y m ch n occ py ng l mit d floo area whe l l ds n a rail r a tie od t tached loc lly Lo d may be t t on ry r they m y b mo i g as with the ca g f c a e h t o with tr k wh el

D t but d l ads e f ces pplied c nt u ly e l ge ar s w th u form non nif rm n te ty Cl ely ta k d c tent o wa ho e floors now o wind pre ur are u if rm load A eq lent iform l ad m y epre e t m ltiple cl ly p ed n e tr ted load Variably d s-tr but d l ad ten tie n l de foundat n oil p es es and hyd o t t c pre e.

Bending and shear T an r fo es p d e b di g m m t d tr s e hear ng f ces t e y ct wh h m t be b l ced by n te al c ple e ti g m ment M nd an ter l tang t al he fo V (F g 1) The e c m p n t f res e e l t d by f ee-body a aly Th b di g m me t a d r ult nt hea fo e an b exp e d a lyt ally a f nct n of the load a d th d t n lo ti g th ti n f om a



Fg 1 B m load g ly s. ( ) By f b dy n l y f b m (b) Co t f g f be d g ( ) C t f g f h

cause death by the massive replacement of functioning hepatic tissue by nonfunctioning tumor tissue The liver is probably the most common location for the secondary spread of neoplasms It is the growth of these metastatic tumor nodules in the liver which is the ultimate cause of death in many individuals with cancer of the bowel breast lung or other tissues *See* NEOPLASIA ONCOLOGY

[M R H]

Bibliography S L Robbins *Textbook of Pathology* 1957 L Schiff (ed) *Diseases of the Liver A Symposium* 1956 H A Smith and T C Jones *Veterinary Pathology* 1957

Living fossils

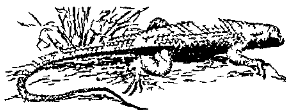
Living species belonging to ancient stocks otherwise known only as fossils They commonly reveal anatomical structures and phylogenetic relationship that at best could only be inferred from the fossils A good example is the mollusk *Neopilina galatheae* dredged from the floor of the Pacific Ocean in 1951 Its known ancestors (family Tryblidiidae) occur in early Paleozoic rocks and were inferred to have been very primitive snails having bilateral symmetry and thus representing a stage preceding the torsion that characterizes all other gastropods The living species prove this inference to be correct but its segmented body also shows that this group constitutes a new class more primitive than the other mollusks ancestral to both the chitons and the gastropods and in turn related to the annelid worms *See* MONOPLACOPHORA

Other examples are the horseshoe crab *Limulus* the opossum *Didelphus* the coelocanth fish *Latimeria* discovered off the east coast of Africa in 1939 and such plants as *Metasequoia* discovered in China in 1941 and the *Ginkgo* whose ancestors thrived with the dinosaurs *See* MARSUPIALIA XIPHOSURA

[C O D]

Lizard

Any of about 3000 species of reptile of the suborder Lacertilia order Squamata Lizards are found in temperate and hot climates throughout the world Typically they are covered with epidermal scales have moderately elongated bodies a tapering tail and two pairs of strong legs on which they run swiftly Most lizards are terrestrial but many are arboreal and several are fossorial or aquatic Degeneration of the limbs has progressed in different groups and a few forms are legless including one common species in the United States the glass snake or joint snake



The fence lizard *Sceloporus undulatus* length to 5½ in (From E L Palmer *Fieldbook of Natural History* McGraw-Hill 1949)

Many lizards are feared as being poisonous but this is true only of the Gila monster and its close relative the Mexican beaded lizard There are both carnivorous and herbivorous species They may lay eggs or produce living young

Lizards are well represented in the United States especially in the South and Southwest Among the more common are the genus *Sceloporus* represented in the eastern states by the fence lizards the genus *Cnemidophorus* best known of which is the swiftly moving six lined lizard the horned toads skinks the American chameleon and the big Gila monster and chuckwalla of the desert *See* CHAMELEON CHUCKWALLA GECKO GILA MONSTER HORNED TOAD SKINK SQUAMATA [J D B]

Llama

An animal allied to the camel and having many of its characteristics but being about one third its size The llama is the traditional burden carrier in the higher parts of the Andes Mountains in South America therefore it has not been bred primarily for its fleece Its hair fiber generally coarse and brownish in color is valued because it may be mixed with the hair of the alpaca an animal of the same species that is raised for its fleece alone Some noils are obtained from the undercoat of the llama



The llama *Lama p o a* length 4 ft (From P M Duncan ed *Cassell's Natural History* Cassell)

When llama hair is part of a blend of fibers it gives exquisite natural colors found in few fabrics Such llama fiber mixtures have a characteristic high insulative property with little weight They are used for high quality coat fabrics to take advantage of the qualities of wrinkle resistance fastness of color and extreme durability *See* ALPACA CAMEL'S HAIR CASHMERE MOHAIR WOOL *see also* ARTIODACTYLA FIBER NATURAL [M D P]

Load line

A line drawn on the characteristic curves of a vacuum tube used to determine the operating range and the quiescent point (the operating point for zero signal input voltage) This graphical construction is necessary because the mathematical func

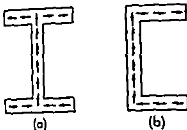


Fig. 4. Shea fl w ( ) I ct d (b) a ch l section.

_hearing tre ses re te s ties of the t ngent al ear f r e distrib ted o er a be m s ti n At a y p t in the beam the ert cal and long tud al ar stresses are q al They a e e o t th boundary urf es and maxim m at the neutral axis. The hear tre_s acc rding to th c mmo theory f fl ure is $S = VQ/Ib$ whe e V is t tal shear f ce, Q tati al m me t bo t the ne tral xis f that area f the be m e t o b tween the level f in estigatio and the t p b ttom f the section, I is m ment of e t a, a d b is w dth In rectangul ecti th d tr bution is p rabol and m imum S i e a d one-h lf tim s the er ge st ess.

hear flow is the hear f ce per nit le gth ting alo g mp e t areas f th secti n The concept f fl s deri d f m the d trib ti n f hear sh r f ces represented by vect rs poi ting i the same d ectio l g the med an line f th n ment and the im lar ty f the xp es on fo ma sh ar to the q atio f r qua tity of liqu d flowing pipe channel (s also TORSION) The d ecti of nit hear force ting in typ al structural sh pe s show Fig 4

Deflection. A beam is said to d rgo deflect n hen the d pl cem t is normal to the o gi l unl ded po it a d s due to c rv tu e prod c d by load Defl tio s may be limited to l ss th n structurally saf al e in buildings to o d cra k g the ceiling or in m chi e becau e f ne e s ry clearan es.

Elastic r i th c rved hape f the l ngi tudinal e t o dal s f ce wh n lo d p d ce only l ti tres e Deflecti at any p t is h ed f m th q at n f th c rv

Radius of urv t d pe ds on the m ment d ul es f th beam nd constant w th be ding to cir lar re, h the m me t is c tant Thi al bending Curv tur e d ar ble m ment, d he r f s c t b t add t n l d ection.

Statically indeterminate beam I the p esenc d mo r tio mpo ents than c n b det r mined by the eq t s f st t c l e beam s statically i det rm te. The fir t tep de gn i to find th ti ns. Eq t of tatics are p-ted ented by dd t n l q t el t g exte tal f es I pe d d flect

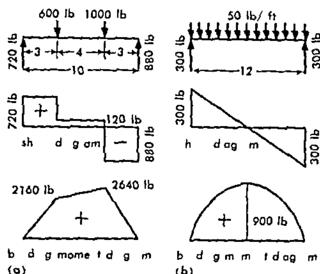
The curv t d c mp n g st e ses d pe d on the load a d th rest ai t imposed by the p-ports In imply supp rted beam only ert c l di plac ment is pre ented at the supp rts whe ea when the beam is fixed otat on is al_o prevented t the ends S milarly beam with o erhanging ends a d beam continuo s v r multipl s pports are partially re trained Intr d ct on of the bo nd ry cond t ons de cr b ng the o d tions imp sed by the upp ts in the lution of the ba ic diffe en ti l equation f r the elastic curve f rn hes rela t ns between the loads reacti n comp nents and p opertie of the b am Duri g el t behavi r these rel t n t gether w th the equat ons f stat cs al at the indetermi ate eacti ns In ela tic beh io i cau ed by plastic deformations t rit c l s ct n of high flexural stre s when the yield po nt of the mater al i exceeded When a fully plast c co dition is re ch d the secti n acts a a pl ti hinge, with con ta t es ting moment dur ng u re trained rotat n The e known mo-m t at s pport or nterm di te po nts permit d terminati n f the re ct ns by the equations of st ti Ad a tage is t ken of th s nel t a tion n plastic des g

Unsymmetrical bending Lo ds that produce be d ng m me ts n pl es bl que to the prin ip l a es of a e tion c u unsymmet cal bending Comp nents of the applied m m nt produce curva ture nd d flect on in pl nes perpendicula t th e axes the st s prod c d by these ompone ts a ting s p rately an be uper mp ed To oid to sio al tw t th blique fo es mu t p s th o gh either the geomet c enter of ymmetr cal ect n o a part c l r p i t c lled the hear cen ter f r un ymmetrical secti ns

Late al buckli g of be ms s aused by n tab l ity f the comp ss n flange which results i l t e l deflect on and tw st f the tion. The ti n r p nd to bu kl g f l g columns The c tic l c mp es e t e p d ing buckl ng de pe ds n the sect al dim n s nd typ of l d g wh h in t d te mine the flang tresses nd t s nal rig d ty of the ect B ams h g small mome t f i ertia bo t the w k with low to io al t t c are sc ptible t buckling Fo r lled beams. buckl ng res st ce related pp oximat ly t the Ld/bt r t whe e L i sp d i beam d pth a d b a d t width and th ck es f th fl ge, resp ct ly

Bu kli g of be m webs c u d by e d go l mp es n duc d by th omplemen t ry hea st e e n th web r by the mbi ed h ar nd be d ng tr s in th web t ng as an dge pp rt d pl t B u e th web s el t ly th n t te d t bu kle l t rally a ene f w es F d ep be m th he st es mu t be ed ced by e d w b th kn ss nf ceme t n the fo m of t ff e gles r pl t dded to i crease e t et late l b kl ng

V ble s ect s m k m re efficient f m te l b m by p o d g r t g m ment at ll ecti m ne ly qual t the appl d m me t If the e t n m d lus s d e tly as th b d g m me t t es M/Z w ll b sta t t



Fg 2 Typ cal shear and moment diagrams for (a) concentrated loads a d (b) uniformly d str buted load

reference origin The magnitude and distribution of internal stresses associated with the external force system are found by the theory of flexure

Bending moment diagram A graphical representation shows the bending moment produced at all sections of a member by a specified loading The bending moment is the sum of the moments of external forces acting to the left of the section taken about the section The sign of the curvature is related to the sign of the bending moment (Fig 1b)

Typical bending moment and shear diagrams are shown in Fig 2 for concentrated and uniformly distributed loads on a simply supported beam The reactions and moments are found for equilibrium (*see* STATICS)

Shear diagram A graphic representation of the transverse shearing force at all ections of a beam produced by specified loading is called a shear diagram The shear at any section is equal to the um of the forces on a segment to the left of the section considered (Fig. 1c) Positive shears are produced by upward forces (Fig 2)

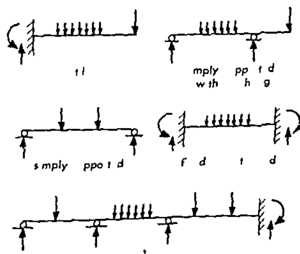
Relationships between shear and bending moment that assist in construction of diagrams are (1) maximum moment occurs where shear is zero (2) area in the shear diagram equals change of bending moment between sections (3) ordinate in the shear diagram equal slope of moment diagram and (4) shear is constant between concentrated loads and has constant slope for uniformly distributed loads Combined loading can be represented by conventional compo ite moment diagrams or by separate diagrams called diagrams by parts

Beams Members subjected to bending by transverse loads are classed as beams The pan is the un upported length Beams may have single or multiple spans and are clas ified according to kind of support which may permit freedom of rotation or furnish restraint (Fig 3)

The degree of restraint at supports modifies the stresses curvature and deflection A beam is statically determinate when all reaction component can be evaluated by the equations of statics Tw equations are available for transverse loads an only two reaction components can be found Fixed end and continuous beams are statically indeterminate and additional load deformation relationships are required to supplement statics

Bending stresses are the internal tensile and compressive longitudinal stresses developed in re ponse to curvature induced by external load Their magnitudes depend on the bending moment and the properties of the section The theory of flexure assumes elastic behavior No stresses act along a longitudinal plane surface within the beam called the neutral surface A segment subjected to con tant bending moment as when bent by end couples is in pure bending and stresses vary linearly across the section which remains plane Simultaneous shear causes warping and nonlinear stress di tribution The stress is maximum at boundary surfaces of sections where bending moment M is greatest Maximum tress S at distance c from the neutral axis to the extreme element of a section having a moment of inertia I is $S = Mc/I = M/Z$ where $Z = I/c$ is called the section modulus a measure of the section depending upon shape and dimensions Greatest economy results when the section provides the required ection modulus with least area The common theory of flexure applies only to elastic stres es Stres es exceeding the elastic limit involve plastic strains producing permanent deflections upon load removal

Inelastic stresses are first produced at surface elements of sections resisting maximum moment A distinct yield point in materials such as structural grade steel cau es stresses near the surface to remain constant while interior stresses increase with increasing load Redistribution of stress continues until the entire section behaves pla tically The fully plastic resisting moment of a standard I section is about 15% greater than the moment ju t producing yield point at the surface Where small increases in deflection can be tolerated this plastic hinge moment is used in design



Fg 3 Types f beam

creased by u if rmity of st ess and d ctil ty Ca pacity to diss p te energy o erloads by pl tic deformati ns is desirable n membe s subj ct to shock impact *See* STRESS AND STRAIN

[W J KR]

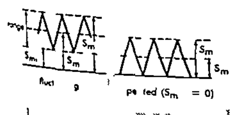
Loads repeated

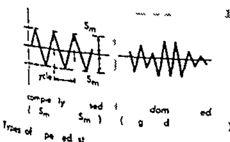
F es r ppl ed m ny t mes c ing v rying stresses as the lo d cha ges Rep ted l ad exist crankshafts, xle pri g piston r ds rails b d memb rs, and many other m chine and structural leme ts. Repeated l ads nsid ably smaller th similarly appl ed st t c lo ds c use failure by pr g es. e fra t re De igns fo re-p ed lo d depend on th maximum alue of repeated t hich the mate l can es t lled the fat gue trength, and the m gnit d of lo alized stress co tr t (*see* STRESS CO CENTRATION)

Cycle of stress The riation of tre s d ing e typ al fl t tio whe the l ad s r peat dly a lied and emo ed or when the l d fluct tes to u u ly fr m t t mpress n is a es cy l (as illu trated) A fluctuat g or pul ting stress ar es betwe m mum and m ni m m alues of th ame ig th cond t n is called pe ted if the stress ed ces t ero in each le. Rev sed stres arie between l of posi e gn d i partly rev ed when the posit t esses e un q al and complet ly re-versed he the oppo te stre a eq l

Stress n tion i deser b d either by the ma im stress, n k d (te n or c mp) and the range f flu tu t on r by the m n t dy stress t gth r th the m gnitud f the per mposed alt rn ti g st e s prod g the y l c ar t n. Repe ted l ad upe mp ed on a con stant load, s h s d ad w ght of the tru t re may p od e fl tuatio w thout re l E g rank h fts nd parts a l a d axles are sub-jected to the rev sed typ cycli l ding wh ch may in l e b ll o s f ep tit s in the l f f the member

Stress raisers D me i al cha g t l discontin i es, r oth r o d ti s causi g l l





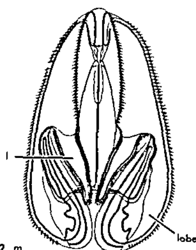
Types of pe ed st

i ed d turbance f th normal stress d tribution w th i rea e of tress e that normally produced a e termed stres rai The maximum stress is called a tress concentration H gh local stresses ex t at bolt threads abrupt ch ge f sh ft d am eter n t hes holes keyways o fillet wells Int r nal di c ntinu ties such as blowholes inclusions se ms cracks d cts d knots n w d v ids in co crete and ariable t ffnes of comp nent o st tue t cause t ess concent atio s At point of c tact f ball or roller bea ings gear teeth r other l al l ad appl tions the tre ma be g eatly ncrea ed Maximum stress is obtained by multiply ng the nomin l tres computed with t rega d to th modifyi g effect of the stres rai er by a t e s once trati n fact This fa tor f und experimentally depend on the type f disc ntinu ity and the pr p rtie f the mate ial under static lo d D tile m teri l rel e es m st of the stress ncent tion by plastic yielding Stre s rai rs ont b te to failure under h gh tres rates and l w temp atu e which t nd t inhib t plastic fl w a d are f gre t import nce und r rep ted lo ds which pr du progre i e f ture c ll d fatigue fail

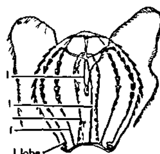
[W J KR]

Lobata

An ord of th Cten phora which the b dy is *helm t haped A pa f la g lobe h ped proc* es es exte d from the oral d in the pharyngeal



L t cyd pp d t g f M m p l dy



beg g f loop

B l ps m k d

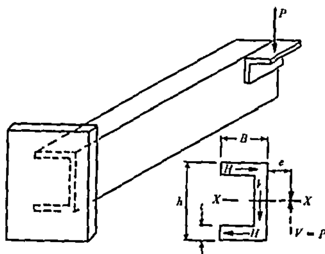


Fig 5 Shear center

all sections and the beam is said to have constant strength Dimensions of the section can be varied by tapering the width and depth or by adding cover plates to a built up section to vary the section modulus Common examples of beams with variable section are tapered cantilevers plate girders with multiple cover plates forgings and other machine elements A leaf spring is a tapered beam in which uniform stress increases energy absorption

Shear center A point on a line parallel to the axis of a beam through which any transverse force must be applied to avoid twisting of the section is called the center of twist or shear center A beam section twists when the resultant of the internal shearing forces is not in the same plane as the externally applied shear The shear center can be found by locating the resultant of the internal shear forces A channel section has one axis of symmetry and is subject to twist unless the external shear passes through a point located e from the center of the web so that $e = B^2h^2t/4I$ approximately when the flange and web thickness are small where B is flange width h is depth of section t is thickness and I is moment of inertia about the symmetrical axis (Fig 5)

Beams on elastic foundation are members subjected to transverse load while resting either on a continuous supporting foundation or on closely spaced supports which behave elastically The curvature deflection and bending moment depend upon the relative stiffness of the beam and supporting foundation Beams of this type include railroad rails on ties a timber resting on level ground a long pipe supported by closely spaced hanger rods or springs and a concrete footing on a soil foundation The unknown reactive force per unit length of beam is assumed to be proportional to the deflection and the solution of this statically indeterminate problem requires derivation of the equation of the elastic curve whose differential equation is $EI(d^4y/dx^4) = -ky$ where k is the spring constant per unit length of support and ky is the elastic force exerted per unit length of beam Solution of this equation determines the distribution of reactive forces from which the shear and moments can be found See STRENGTH OF MATERIALS

[W J KR]

Loads, dynamic

A force exerted by a moving body on a resisting member is called a dynamic or energy load Loads suddenly applied with appreciable striking velocity as when a falling weight strikes another body are called impact loads Such loads are produced by moving machine parts cars on a bridge airplane landing shock falling weights and other nonstationary loading conditions where forces are applied in relatively short time intervals Dynamic load is expressed in terms of the amount of energy transferred or by an equivalent static load which has the same stress producing effect on the member

Impact or load factor is the measure of the increased static load required to produce the same stress as the dynamically applied load It is thus the ratio of the equivalent static load to the weight of the moving body Impact affects both the magnitude of the stress and the properties of the material Increased strain rates associated with impact increase the elastic and ultimate strength

Elastic behavior If a material or structure has sufficient elastic energy capacity as a resisting member to absorb completely the energy load through elastic action and recover completely from the deformation it behaves elastically (see SHOCK ABSORBER) Elastic stresses associated with stored strain energy depend on the kind of deformation produced Part of the kinetic energy is dissipated by deformation of connections friction and inertia effect

Dynamic stresses and deformations can be found by equating externally applied energy to the internal strain energy expressed in terms of stresses and dimensions Dynamic force produced by weight W falling through height h onto a beam or spring is approximately

$$P_{dy} = W + W\sqrt{1 + \frac{2h}{\Delta_{st}}(c)}$$

where Δ_{st} is elastic deflection due to gradual application and c is an inertia correcting factor Stresses and deflection are found by expressions of the same form

Inelastic behavior An energy load exceeding the elastic energy capacity of the member produces inelastic deformation For a known amount of energy the dynamic load and deformation can be found approximately from the boundaries of the area under a statically determined load deformation curve which represents absorbed energy Similarly the inelastic stress produced by impact or the dimensions necessary to limit the stress can be found from areas in the static stress strain curve

Toughness is the energy absorbed per unit volume when the material is stressed to fracture and is represented by the total area under the stress strain diagram Ability to store strain energy is in

creased by unif rmit f stress and d ct lity Ca acity to di pate energy e loads by plastic deformations is desirable in members subject to work im act. e STRES D STRAIN [W.J KR.]

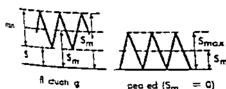
Loads, repeated

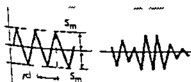
Forces re pplied man times aus ng ary ng stresses as th load changes. Repeated l ds exist n rankshafts, axles pring pi t n rods rail. bridge members, and many ther m chine and structural lements. R pe ted loads n derably smaller than similarly ppli d tatic loads c use failure by progres e fracture Des gns f r repeated loads depend n the maxim m al e of repeated stress hich the mat rial c n res t called the fatigue tr ngth, and th magnit d f loc lized stress ncentrations (s e STRE CO CENTRATION)

Cycle of stress. The ariation f tr d ring ne typ al fluctuation when th l d is epe tedly applied and em ed r when the load fl ctu tes ntinuou ly f m ten n to c mp es io is a stress cycle (as illustrated) A fl tnating o p l si g stress aries between m ximum and m nimum alues f the am s gn this c nd ti n is called eperated f th tres red ces t ze n each le. Rev rsed tres aries between lues f ppo ite gns d partly reversed wh n th pposite stresses are qual and compl tely eersed hen th pposit t es are qual.

Stress ariatio is described e ther by the maximum stress, its kind (t nsio r ompres) and the rang f fluct tion , or by the mean or te dy stress together with th magnit d of th per imposed alternating tr prod ing th cy li ariation. R peated load p rimposed n c nstant load, such as dead w ght of the tru tur produce fl ctuatio with ut reversal. Engin crankshafts and parts, rails and axles are ubjected to the eversed-typ cyclic l ding, whi h m in l billions f epetit ns in the life f th member

Stress ra sers. Dimensional han es internal discontinuities. the nditions u g local ized disturban e of the normal tress distribution, w th in rease f tress er that n small prod ced, are termed tres raisers Th maximum stress is called tress conc ntrati n. H gh local stresses exist t bolt threads, abrupt hange of haft diameter n tches h les, keyways r fill t w lls. Inter nal d sc tinu t es ch as blowholes, inclus n seams r cracks, d cts and knots in wood, id n c ete and ariable t ffness f mpon nt c n tit ents c use stres oncentrations. At poi ts f c ntact f b ll r r ller bearin g ar teeth, r th r local l ad appl at on th t es ma be gr tly in r ased. Maximum stress is obtained by m ltiplying th n minal tress omputed w thout re ard to the mod fy ng effect f the tres raise by tress co centr tion fa tor The fact r f und experim ntally depends n the type f disc ntinuity and the propert es f the mat rial under tatic load. Du til mat rial rel eves most f the tres c n ntrat n b plastic y lding. Stres raiser ntribut to fail r under high tress rates and l w t mper tures which tend to inhib t plastic flow and ar f gr t importan e under r peated loads wh h produce pr gres e fracture, called fatigue failure. [W.J.KR.]

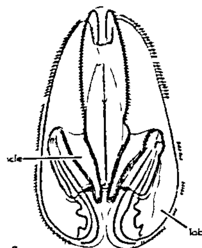




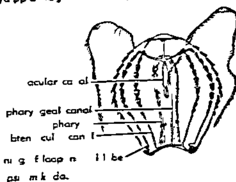
Types of ed str ss.

Lobata

An rd r f th Ctenoph r in which the body is helmet-shaped. A pair f large lobe-shaped proc esses extend from th ral end in th pharyngeal



L t cyd'pp d tog f Mn m psis l dy



beg ni g f loop n l l be

B l psi m k da.

plane A pair of auricles are attached to the base of each process The body is compressed with the tentacular axis being shorter than the pharyngeal axis The ribs are of unequal length with the long est being the subpharyngeal pairs The primary tentacles are degenerate and are replaced by sec ondary tentacles The canal system is complex Ex amples of this order include *Bolinopsis Ocyropsis Mnemiopsis Leucothea* See CTENOPHORA TENTACULATA [T K]

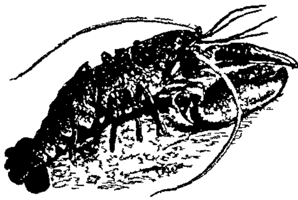
Lobster

A name usually limited to a member of the family Homaridae order Decapoda class Crustacea phy lum Arthropoda The family includes nine genera of which only one is represented in American wa ters by a single species *Homarus americanus* the American lobster

This species is the common lobster of commerce It is a valuable animal supporting an important fi hery in the New England states The annual catch has exceeded 100 000 000 lb but due to de pletion it has been much less in recent years For example in 1954 the total catch was only 27 000 000 lb 1 000 000 lb coming from the middle Atlan tic states and the remainder from New England Depletion has been caused primarily by overfishing and by catching lobsters before they could repro duce Lobsters must now be returned to the water unless they are over 12 in long or have freed the first generation of young

Lobsters are essentially like the fresh water cray fishes in their tructure differing mainly in size The average American lobster is a little over a foot in length and weighs about 2 lb The record speci men weighed over 28 lb and was 2 ft long Lobsters are usually dark green with darker spots and yel lowish beneath The animal turns red only after it has been boiled

Like the crayfish the female carries her eggs un der her abdomen until they hatch A 15 in female may carry as many as 100 000 eggs at a time Mat ing occurs some time before egg deposition usu ally in the spring with the eggs being liberated early in the summer The young re emble their par ents in form They undergo about 25 molts before



Lobster *Homa us amer ca us its length s to 2 ft (From P M Duncan ed Ca sell's Nat l H story Cassell)*

attaining sexual maturity at 5 years of age The female frees her first brood of young when she is 6 years old and produces a new brood every other year thereafter

In recent years the shortage of the American lob ster on the market has brought the spiny lobsters of the family Pallinuridae into commercial promi nence There are two commercially important pe cies the California spiny lobster *Panulirus inter ruptus* on the Pacific Coast and the sea crawfish *P argus* on the Atlantic Coa t The latter is a southern form found from the Carolinas southward and in the Gulf of Mexico Together these animals produce about 3 000 000 lb of food annually about two thirds of which comes from the eastern species Both species are 8 in or more in length and are identified by the strong spines on the carapace. *See* CRAYFISH DECAPODA (CRUSTACEA) [J D B]

Location fit

Mechanical sizes of mating parts such that when assembled they are accurately positioned in rela tion to each other Locational fits are intended only to determine the orientation of the parts For nor mally stationary parts that require ease of assem bly or disassembly for parts that fit snugly and for parts that move yet fit closely as in pigots slight clearance is provided between parts Where accuracy of location is important transition fits are used In these fits the holes and shafts are nor mally nearly the same diameter For greater ac curacy of location the shafts are made slightly larger than the holes such fits are termed location interference fits *See* ALLOWANCE. [P H B]

Locomotive

A vehicle supported on wheels capable of self propulsion by converting heat or electric energy into mechanical power for the purpose of moving railway cars over rails It may be powered by steam compressed air electricity oil or gas from volatile oils.

A locomotive consists of a power plant for gen erating energy a storage compartment for fuel a transmission system for converting energy into me chanical power a system of controls for governing the power developed a braking system for reducing the speed of the train and auxiliaries for lighting heating systems for pas enger trains warning sys tems and devices for increasing unit efficiency The three general classes are passenger freight, and switcher

Passenger locomotives are designed for high speed fast acceleration and light loads The steam locomotive has large diameter dri ing wheels (69–84 in) electric motor driven units have low gear ratios

For freight service locomotives are designed with slower speed and acceleration than passenger loco motives to pull heavy loads Steam locomotives use maller diameter driving wheels (63–70 in) electric motor driven units ha e higher reduction gear ratios



ig. 1 Mod rn team passe g r l m t d el ps tractive ffort f 80 000 lb pl d l gth f g e d tender 109 ft t tal w ght 872 600 lb (N lk and W st R ilw y)

Flexibility i of first importance n a lo om t e switching serv e It mu t m e eas ly in either direction, be able to negotiate h rp urves ha e good id learan e f r mo ement i yards and in industrial a as, d pr ide good i b l ty for the engine cre

Steam locomotive This type c n t f two main parts co nected by a art ul ted joi t. The tender at th r a m nted o idler wheel the ab, fi e box, a d bo l r located the m in f ame m unted the d ng wh els (Fig 1) In an articulated type locomot e, the m n f am re ts on tw separ te dr g t ks.

Steam is generated a fire t be b il r using coal r il for f el. H t f om the fire box p s es through boile t bes (F g. 2) h at g water to produce steam. h h p ses thro gh ontrol l s into th main cylind r wh e it act p n the driving p t Ea h p to is on ected thr ugh the cross-he d d dri g rod to th dri ing wheels, h h e ected to e h the by s de rods. Th od nection is ff the wheel center forming k s that the l r m ement f the pist ses th he l to rot te a d mo the loco t e.

Loc m t peed trolled by a th ottle hich g rn the am t f team e te ing the linder t e time, and th t-off l e which de rmines th tim ng Th se l s a i te n ted th th s-he d the by t m ng th r ning and l g t th m m t of the p ton The locom ti e ever ed by m han m that change the flow f team to the pp site end f the pi t n ylind r

Coal i fed int tl e fire l x l y l and or a t matic stoker In o l fired l c m ti e oil i f rc d in th ough n zzles Water is f r ed into tl e b iler by an inject r tl ugh a check val e tl at pre ents the steam fr m ba k ng p The effc ency of the team eng ne i increa ed by p eheat ng the water bef re it enters tl e l ler a d uperheating tl e team bef re it nter tl e cyl nders

Electric locomotive Th lo m ti e c nvert electr c energy prod ced o the t ide to m tive f rce through its ele tric m t rs It ha the ad a tage of perati g fr m an en rgy s urce that is limited only by the rating f the ele tric tran miss n system C rre t is p cked up l y third rail ho s or erh ad pa t graph and i either used directly by th m t rs or is on rted by transformer m t r lte nators or r ctifier to a f rm usable by them (F g 3)

The power is determined by the number a d characte tic f the elect c m t rs I it ally the m t r a m tur wa m u t d on the xle now the m t r hu g in the tr k and g ared t the axle by a pin o ge r n the armature haft and bull gear n the xle Starting and a celerat on require h gh c r nt pe d require high ltage

Locomoti peed i c ntr lled through m t r tr n ti n a d by multiple tep r tors A the peed in ea s th current drops requ ri g higl er oltage whi h s btai ed by cutting o t re i t n e nd by t ns ti n Tra s t on i cc mpli hed by ope ing nd clo ing p wer tact rs to f rm e es e s-parallel r full par ll l mot r cir c t Ma imum p ed i l m ted by m tor co tru tio a d gea rat The l m t e s r e ed by re er ng the flow f urrent th ugh the m t r fi lds. An ad ant ge of lect c powered l moti s is th t tw or m unit an be op rated n multiple by e w by t ai l ning thei co trol r it thu multiply ng the r p w r for hea y t ai and te p gr de

Ele t c tr mi on also lends t elf t dynamic r g n r ti e b ak g th r it are ch ged to make gene to f the mot which pump urrent ba k t the l ne o d ipat th ir load in forc d i o led re st rs

Diesel locomotive A iabl peed d el n gin wh h bu ns fu l o l p w rs this l c mot e Th e g e type u u lly u d re four cycle V type f u cy le li e two- ycle V type and pp ed p t n typ They range n e fr m 150–2400 hp h gher hor powe un ts re qu pped with bl we s pe harge Speed of the n g e c t lled by t g e n wh h m asu th q t ty f f el ject d nt the cyl nder th th ittle me ha m i link d t th g rno Se l typ f t m n e n g e al use g a hydr ul c nd l tr

G t smis H th d l s n ted t th d g wheel th o gh t a miss of ha ge ble gea t s th t p de f r e g d h ng g the peed f th un t.



Fig 2 Flo f hot mb t p d t f m t b f locom tive boil th gh m k h t d p t k

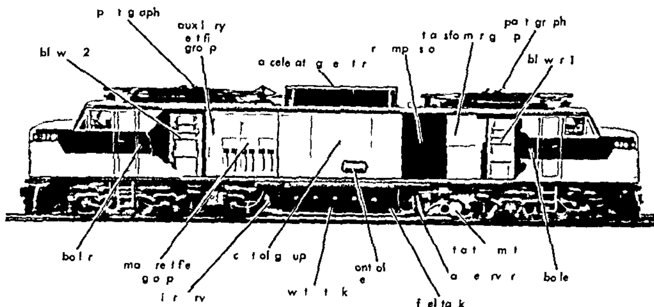


Fig 3 Rect f er type elect ic locomotive for pa senger and freight service has max mum peed of 90 mph s 68 ft long weighs 348 000 lb and develops 4000 hp (General Elect c Co)

Hydraulic transmission Here the diesel engine is connected by universal drive shafts to the hy draulic transmission system mounted on the truck between the two driving wheels One type is an automatic gear shift mechanism with a disengaging torque converter it provides four speeds forward and reverse

Diesel electric locomotive By far the most popular locomotive in the United States is the die sel electric type (Fig 4) Its power is the variable speed diesel engine its transmission the flexible electrical system of generator and motors

The generator driven directly from the diesel engine provides electric power for the motors lo cated on the trucks and geared to the driving axles The generator is separately excited by an auxiliary generator driven by the die el through gear trains or V belt This or other auxiliary generators simi larly driven provide power for auxiliaries and bat tery charging The die el engine is started by using the generator as a motor with the battery supply ing the power

The air compressor that provides air for the braking system and air operated auxiliaries is di rectly connected to the diesel Fans for the cooling sy tem and traction motor blowers are geared or V belt driven from the diesel In some models the fans are driven by ac motors powered by an ac alternator built on the end of the main generator

In starting power is increa ed by increasing en gine speed After full engine speed has been ob tained motor tran ition and field hunting are u ed to obtain higher locomotive speeds

The speed of the diesel engine is controlled by its governor To balance the power demand of the electric generator and power output of the diesel a load regulator is connected to the governor

Heating for passenger ervice is supplied by a steam generator

The development of the die el has brought a new type locomotive into prominence the road switcher Constructed similarly to the switcher it has suffi cient power for either light passenger or local freight ervice and being adaptable to multiple unit operation it is a versatile piece of equipment

Turbine locomotive This type locomotive is powered by a steam or gas turbine (*see* GAS TUR BINE STEAM TURBINE) The turbine power is trans mitted to the dri ing wheels through an electric transmi sion system

A modern steam turbine coal fired locomotive is rated for 4500 hp It has a starting tractive effort

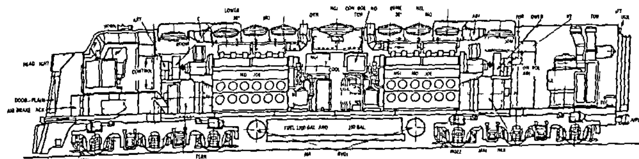


Fig 4 Diesel-elect c locomot ve rated for 2400 hp 70 ft long a d we ghs 324 800 lb load d (Gen al Moto s)

d 1"000 lb tinu s rating of 144 000 lb at g h d m imum peed f 60 mph Its upled length, incl ding ter te der is 161 ft. A water tube boiler pr des te m at 600 psi and 900 F

A odern l b rning gas t rbine was put int ser e th U P cific Rail y in 1958 It is rated at 8500 hp f r tra t on t 6000-ft ele ation t 90 F and is des gned for h gh peed l g-di t e ght run tra k ge ha i g a 6-mi 1 14% grerning grade. It h t o main its and e 4 00-gal fuel t ailer e all le gth 1 5 ft weight on drivers 828,000 lb, maximum peed 65 mph continuou sti 145 600 lb tra ti e eff rt at 18 h, and dynam c braking fo ce f 147 000 lb at 22 h.

Th A un t ta s the a liar es, i cl ding a 6-cylinder diesel gine c pable of p pelling the locom tive and l aded f el tr il r at 20 mph The B unit c t the g s turb ne gener t r pow r unit.

Fig. 5. Typical rv f t ct ff rt f ct f speed f th bo c type f l m t s.

A gear bo bet ee po er plant nd ma n gen unit redu es the 4860-rpm tu b n p ed t 1050-rpm main gener to peed Ea h f th f ur m generat rs d es thre four pole, series-w und traction m t s, mounted in e tru k and gea d to th xles ha ing 40-in.-diamete wheels. At l w speed (0–42 mph) th three mot s of h t u k are connect d n p llel w th on g n at a d one t p f fi ld hunti g at h gh peed (42–65 mph) ta t rs econn t th powe ir uit w th tw g t in series nd dri ng ix m tor n parall l. Th s ectu n inc ase th g ted ha fr m 800 t 1200 hts a d p vid bett power utilizat n at high peed

Locomoti e characteristics Capacity of l co-motive is ted in terms f tr ti e eff rt. St rti g tractive ff rt indicates loc m ti b l ty t "break ut a train f m a tand g tart. H e-power dev l ped at r t d speed i d ates th t ff rt th t an be expected t a sp eds.

Tr ctu effort Th forc d lo ed by the power pla t at the d iving wheels i the tracti e ffort It max mum alue l mited b y the unit po er pl nt its u al le alue, by the we ght n dri er a d th r coeffici nt of adhes n t the rail F r starting n dry r l 25 l weight n dri e s is c idered rm l tracti eff rt up to abo t 15 mph F r steam tracti e eff rt i alc l ted fr m th d men n of the l moti e for electric dr e f m th power del red t th m tors (Fig 5)

D aub r p ll Th t f rce d el ped by the l co-m ti e nd a lable at the drawbar f r pulling train is drawb r pull It loc m ti e tr ti e ffort les the f rce necessary to mo e the loco-m ti e.

T n sista c Th ret di g f es c u ed by be ring fr ti n ra l f cti n and w d resi t an e are lumped a train res ta ce. St ti g or b eak away re tance three times th t f tra n re t n e at nif rm eed f 5 mph

G ade r sista c That f r e r tard ng the m ve-ment f a tr n p a gr d is g ade resi tan e It i mm nly 20 lb p r t n per 1% f g ad

A c l ating sist nc Th f r e th t retard the n rease f train p ed in l d ng inert is a el at g es ta ce To o e me th s, a force necessary t a el ate the tr in we ght nd the r tat f t tat g parts On m le per h ur per sec nd a el rat requires n t f e of 100 lb pe t n of trai

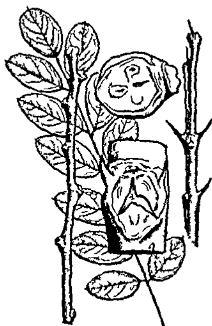
C sistan e That for e resi ting the m e-m nt f a tra n r d rve i alled rve re-i t n The type nd fle b l ty f the tr d t r m nes this It s est m ted to be betw en 0 4 nd 0 8 lb p t n f t a n

Cold u th st ta e Mo t ra lr d adju t the r train t n ge d r g c ld w ather t ll w fo effe ts l mped as c ld w th e t n e. The e figure ry f diff nt rail ads an a rag is 5% redu ti n f a h 10F nc me t dr p bel w 40 F S RAILROAD E GI EERI G [C.A L.]

Locust (forestry)

A name mm nly applied to two trees, the black locu t, *R b ni p ud ca a* and the h ey loc st *Gl dit ia tria nthos* B th of these ommerci lly mp rt nt trees ha podlike fru t s m la t th se f the pea be n S LEGUME.

The bl k lo u t whi h may tt a he ght of 75 ft, s at in th App l h d the Ozark e-gi n nd i n w widely n t r li ed in the a t rn U ted Stat s o th rn Can d and E r p It hara t r zed by odd p te l e f gr nt wh te bl m l ke th e f p plant n l ng l ters, flat br wn pod 2–4 i l g a d p f t p l th rns t the ba f e h l f In wi t th pai d th rn d th p po d buds h dd n nder the l f ar mp rt t d ti gu h g fe tur Th w d ha d a d durabl in the so l nd i ed f f p t m n timbe pol and a l d t It th p n ip l wood f r n ul t pi n t l ty pol B e f t w de-



Black locust Rob n a pse doacac a (A H Gra es Illust ated Gu de to Trees and Shrubs Ha pe 1956)

spreading fibrous root system which support nitro gen fixing nodules the black locust is well adapted to erosion control and soil reclamation (*see* SOIL CONSERVATION) Many varieties are planted as shade or ornamental trees

The honey locu t which reaches a height of 135 ft is native in the Appalachian and the Mississippi Valley regions but is also widely naturalized in the eastern United States and southern Canada The flowers are inconspicuous but the large brown fruit pods (12–18 in long) are striking The tree may be easily recognized at any season of the year by the branched thorns growing on the trunk or branches The leaves are either pinnate or bipin *nate The reddish wood is hard strong and coarse* grained and takes a high polish Because it is dura ble in contact with soil it is used for fence posts and railroad ties it is also used for construction furniture and interior finish Although it belongs to the legume family the roots do not possess nitrogen fixing bacteria The tree is often used for hedges as an ornamental and for shade *See* FOR EST AND FORESTRY TREE [A H G]

Loess

An essentially unconsolidated unstratified cal careous silt Most commonly it is homogenous permeable buff to gray in color and contains cal careous concretions and fossils In natural and artificial excavations the loess maintains notably stable vertical faces

Texture and composition Mechanical analyses of loess show that fine sand (*grains* $>0\,074$ *mm*) comprises 0–10% silt (0 074–0 005 mm) com prises 50–85% and clay (grains $<0\,005$ mm) comprises 15–45% Variations in published analy ses *may result* in part from the different grade size limits used by the investigators Although domi nantly silt and often referred to as well sorted loess is actually only moderately well sorted The silt (and sand) grains are usually angular to sub-angular Clay occurs as silt size aggregate as coatings on silt grains and as interstitial filling

The silt and sand fraction of the loess has the following mineral composition quartz, 50–70% feldspars 15–30% carbonates (mainly calcite) 0–11% and heavy minerals 5 15% X ray identi *fication of the minerals in the* $<0\,005$ mm fraction show abundant quartz plus varying proportions of montmorillonoids illites and chlorites In texture and mineral composition loess is comparable to the average mudstone or shale It is su ceptible to authigenic changes such as the transformation of clay mineral formation of chlorites and the movement of soluble materials especially carbon ates *See* AUTHIGENIC MINERALS CLAY MINERALS SEDIMENTARY ROCKS



Loess depos ts of the world (F om A K Lobeck Geo- mo ph l gy M G aw H ll 1939)

Occurrence and origin Loess is typically de-veloped in areas peripheral to tho e covered by the last ice sheets in America and Europe Greatest thicknesses (more than 150 ft) occur in the uplands bordering the valleys of the major treams There is a general but irregular thinning of the loess in one or more directions away from each valley Other *notable areas are nothern China and Argentina* Mo t of the loess seems to have been deposited dur ing the latest (Wisconsin) glacial stage Little or no loess is found associated with earlier glacial de posits or covering the area actually occupied by the latest ice sheet No loess deposits older than the Pleistocene are known

Many theories have been proposed to explain the deposition of loess The most widely accepted the *ory is that the materials were transported and de* posited by wind Source areas were nearby flood plains and till plains Controversy continues how ever for some investigators present evidence and arguments in favor of the alluvial origin of some loess Others hold that primary deposits by wind or water have been greatly modified by colluviation to produce loess *See* SEDIMENTATION (GEOLOGY) [C J R]

Bibliography A K Lobeck *Geomorphology* 1939 F J Pettijohn *Sedimentary Rocks* 2d ed 1957

Logarithm

An exponent of a suitably chosen positive number (base) larger than unity Logarithms are of value in mathematical computation and in the equations

d form las u ed in e pressing natural phenom ena.

The in e ti of nat ral logarithms (ba e e = 2.718) is ually attributed to J hn Napier who p blish d a table of logar thms in Edinburgh 1614 und the title *Mi fici Logarithmo um Can nis De criptio* e en though the fun tio s tabulated by N per a e merely related to a d not identical th, the n tural logarithms.

The in ention f c mm n l garithms (ba e 10) is gener lly attributed t He i Brigg Nap er s share ackno ledged ho e er by Brigg him elf in his *Arithm tica logarithmica* n 1624

Theory If $b = n$ her b a po iti e n mber larger than nity then l i called the logarithm of to the b e b and is written $l = \log_b n$ From this definition it foll ws at e th t all po ti e numbers larger than u ty ha e p itive l g thms, all positive mber maller than u ty h e neg tive l garithms, and the loga thm of unity is equal to 0. Si ce b = 1 irrespecti e of the alue f b it follows th t th l gar thm f nity i eq al to 0 F m the k n properties of expone tials ex pressed by th elati s

$$b^{l_1} b^{l_2} = b^{l_1+l_2} \qquad b^{l_1} \div b^{l_2} = b^{l_1-l_2}$$

$$(b^{l}) = b^{l} \qquad \sqrt[m]{b} = b^{l/m}$$

it f ll imm d ately th t (1) the l garithm of a prod ct f t r m e factors is equal t the s m f the l garithms of the fa t (2) the logar thm of the atio of t mbe s is equal t th diffe ence bet een the l g thm f the n merat r and the l gar thm of the denomin t r (3) the l ga rithm f th mth p wer of a mber th prod t of nd th l ga thm f the number and (4) th l arithm f the mth root of mbe equal to the lo arithm f th n mber d ded by m These pr pert es are e po ble f r the great simpl fica tion in th task of c rrying out n m r al c m p tations i l ing m ltiplicatio d n ra s ing umbe t ertai p wers t t g the roots f certain o der of gi e numb It lso follo fr m these p pert es th t in construct g table f l garithms to a c rtai b e fr m th beginning, the comp te need only mp te the l g rithms f prime n mb r b cause the log rithm f an numbe h ch s n t p im may be obtained from the l garithms of its p ime f ctor by simple per ti ns f dd ti n nd m ltipli tion. *See* Ex PO ENT

Alth gh y p t e umber b l ger th unity m ght ha been ch n s th ba e of a system of l garithms, a tually two umb s ha e been hose i the n tr ti n f tables of l g ithm na ly th umbe $b = 10$ d the mb de fined as th um f the nfin t se e

$$1 + \frac{1}{1} + \frac{1}{1 \cdot 2} + \frac{1}{1 \cdot 2 \cdot 3} + \cdots + \frac{1}{1 \cdot 2 \cdot 3 \cdots} + \cdots$$

The ystem of l garithm t the b se 10 s usually referred to as n l g r thms the y t m f l garithms to the b se e is called natural l garithms

Comm n logaritl ms l a e certain obvious ad an tages n t shared by natural log rithms All num bers between 1 and 10 ha e logarithms betwe n 0 a d 1 all n mber between 10 a d 100 ha e logarithms between 1 a d 2, and so on Thus the integral part of the c mmon logarithm of a number la ger than u ity i one init less than the number of digits bef re the decim l point Thi integral p rt i called the *haracteri tic the de mal part* i called the mant sa Similarly becau e the m mon l garitl ms of 0 1 0 01 a d 0 001 a e -1 -2 and -3 it f llow that the l garithm f a number sm ller than unity having p zer fter the decimal point may be expres ed a the sum f a nega ti e char cter tic eq al to $-(p+1)$ d a po i t e m ti sa

Natural logarithms Becau e the number e = 2.718 the b e of the system of nat ral log rithms is irration l th t is it cannot be expres ed s the rat o of two integers (a d theref re when ex pres ed as a decimal umber it in ol es an i finite number of decimal with no repeating gr ups of d cimal) It m ght seem odd therefore that it has been hosen the b e of a sy tem f logarithm The *primary moti ation f r this choice lies in the* fact that the lutions of numer us problems in appl ed m themati are m t natu ally expres ed in te m of powers f e Thu for inst nce the sol tions of the probl ms of eq ilibrium f a flexible cable, the t ient fl w of electric current in a rcuit a d the di i tegrati n of radioacti e element r expressed in terms of e^x where x is ei th r po iti e r negati e and depends on the physical pa meter of the probl m in qu t n Thus, *the tabulat f the f ncti n e^x f r both p iti e* and negati e l es of x was an ind sp nsable aid obtai g the sol t ns of many phy ical problem Beca the logar thmic f t n i the in e e f the e p ential f tion a table of n t ral l gar thm can be nstructed w th relati e ea e f m a t ble of e^x by the process of e e ter p l t on. An ther moti at n for constructi g tables f natu al l garithms th fact that natural loga thms a se th integr t n f q t ent of poly m als nd of f ctions wh ch may be approx mated by q otients f p lynomials Indeed it is a well kn w fa t th t f th n o ts of a p lyn mial $Pn(x)$ a e k own so th t $Pn(x) = a_0(x - x_1)(x - x\ )\ \cdots\ (x - x\ )$ d if $Q(x)$ i p lynom al of deg smalle th n then the quotie t $Q(x)/P\ (\ )$ may b p d i the f rm

$$\sum_{k=} \frac{A_k}{x - x_k}$$

wh n the A may be e ly d t rmined A cord i gly

$$\int [Q(\ )/Pn(\ )]\, dx = \sum_{k=1} A_k \int \frac{dx}{x - x_k}$$

$$= \sum_{k=1} A_k \log\ (x - x_k)$$

Table of logarithms

Number	Natural logarithm	Common logarithm
0 01	86 − 10	− (8 − 10)
1 0	0	0
e = 718	1	0 4343
10	2 303	1
1000	6 909	3

Relation between logarithm bases Let l_1 be the known natural logarithm of a number N What is the common logarithm of N? Clearly $N = e^{l}$ and therefore $\log_{10} N = l_1 \log_{10} e$ Since $\log_{10} e =$ 0 43429 (to five decimals) it can be concluded that natural logarithms are converted into common logarithms by multiplying the natural logarithm by the factor 0 43429 which is called the modulus Similarly the common logarithm is converted into *a natural logarithm by division by the modulus* 0 43429 or multiplication by 2 303

Logarithms of complex numbers Since b^{l} is po itive when b is positive negative numbers have no real logarithms Neverthele Euler s famous formula $e = \cos\theta + i \sin\theta$ where $i = \sqrt{-1}$ makes it possible to define not only the logarithm of a negative number but also the logarithm of a complex number Indeed any complex number $a + ib$ may be written in the form ρe^{i} where $\rho = \sqrt{a^2 + b}$ and $\theta = \arctan(b/a)$ It follows that the logarithm of a complex number $a + ib$ is a complex number whose real part is the logarithm of its modulus ρ and who e imaginary part is its phase (or argument) θ Because $e = e^{i(}$ it follows that a complex number has an infinite number of logarithms given by the relation

$$\log(a + ib) = \log\sqrt{a + b} + i(\theta + 2n\pi)$$

where n is a positive or negative integer

As previously mentioned the evaluation of natural logarithms may be based on inver e interpolation in a table of e For small values of x positive or negative one may use the expansion

$$\log(1 + x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \cdots + (-1)^{+1}\frac{x}{n} + \cdots$$

This expansion may be derived from Taylor s series

$$f(x + a) = f(a) + \frac{x}{1} f(a) + \frac{x^2}{1 \quad 2} f(a) + \cdots + \frac{x}{1 \quad 2 \quad 3 \quad m} f^{()}(a) + \cdots$$

by writing $f(x) = \log x$ After a sufficiently accurate table of $\log(1 \pm x)$ for $x = k10$ $k =$ 1 2 3 9 and $n = 1$ 2 3 N where N is sufficiently large (perhaps 15) has been computed this table may be used to compute the logarithm of any number From the above expansion for $\log(1 + x)$ it is ea y to derive the expansion

$$\log p = ½\{\log(p - 1) + \log(p + 1)\} + S(p)$$

where

$$S(p) = \frac{1}{2p^2 - 1} + \frac{1}{3(2p^2 - 1)^3} + \cdots + \frac{1}{(2n + 1)(2p^2 - 1)^{2+1}} + \cdots$$

which has the virtue that $S(p)$ converges quite rapidly Thus for $p > 10\,000$ the error resulting from neglecting all but the first term in $S(p)$ is considerably less than 10 See e NUMBER THEORY NUMERICAL ANALYSIS [A N L]

Logging (forestry)

The first step in lumber manufacture is harvesting trees from forests in the form of logs and delivering the logs to a sawmill See LUMBER MANUFACTURE

Equipment Felling trees elected for cutting is accomplished with hand saws or by power aws The chain type gasoline powered saw with cutting teeth in a chain moving rapidly around the blade is the most widely used (Fig 1) Trunks of felled trees are severed at log length intervals to the point of minimum merchantable ize or quality in the top Most log lengths are 12 14 and 16 ft corresponding to the tandard lengths of lumber used in general construction although other lengths are cut for special needs

Logs are skidded short distances over unimproved terrain to an assembly yard or a loading point on a logging railroad a truck hauling road a winter sled road or a stream in which the logs an be floated or loaded on barges This requires considerable power as do all subsequent steps in logging For example a longleaf pine log 16 ft long and 18 in in diameter weighs 1500 lb Logs are skidded by mobile power units such as a hor e or a



Fig 1 A logg f ll ng a l ge t w th a m ch n pow r aw (Ph t g aph by Hom lite C p)

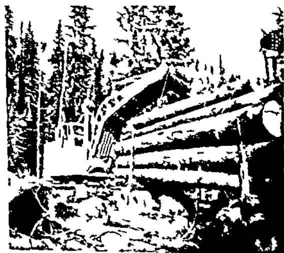
tracto r b t u ary d e l pow r u it with drums d bles. The m bile u t goes to th l gs a d pull them to the ro d ide. With a st u nary un t, l gs are fa te ed to the nd of a c ble and a it nd the drum th l g a e pulled t it A id ariety of types nd ze of kidd g equ p ment b been pe fected t meet ar at n f umbe ze, t rr i and de ty f the t nd t be ut.

Methods. Att chme ts ed t fa te l gs to k d d g dev es re to gs imil t ce to g or h k rs resembl g l p oo es pl ed a u d the ds f l Whe the gr nd i too swampy to pport anim ls t t rs or too teep c ble k d d g is ed The h gh fi ed c t f cable skidding install t s qu s m im m d ly log lumes 1 50 000 ft 10-ye r perat ng life nd ta d ging 10 000 ft/ e. The mple t f m f bl k dd g c t f d agg g log n the gr d t th m h ne w th or without a cable h l A m h m wid ly ed method is th high l d w th t ha l With t the p lli g c ble s led from th p ll g d m th gh a p lley block fa t ed 30–150 ft up t ee r p r and th n t to th k dd g a. A l ghter c ble gged to p ll the k dd g able rap dly o t after a load ha bee k dded Whe k ddi g has been mpleted m s h ar a, the r haul block re el ted and th k dd g l m ed t the dj ent seg ment. I ll bl kiddi g m lar p tte n is f l lo ed, that th t f m g ar nd the rel until the t with l g has be n c e ed A h d bl st et hed betw a h d par t the po t d suc e e tail pa at th f r edge f the kidd g lso used wh th kidd g d t ce d th t at wh h the high le d m thod ffe t The e e l o e he d method b t all th k dd l ne ext d up the h d par thr gh a t ll y block th t ride the ain c ble t et hed bet ee the p and then t th gr d h l gs be fa te ed t it The kidd g lin p tted al g the sk dd g tr l by the k dd man s ted by gnal me A l d f l gs i p rtly r wh lly ed bo the g nd d th p ll d by th t ll y t th h d p r C d kidd g a be used ffecti ely f r d s ta es f 300–400 ft Th h gh lead meth d s ef fecti t 400–800 ft, d p d g on the h ght f th high l d block Ov he d bl k dd g h w ever b u d p t ¼ m le or f rthe Wh t tr p rmits m b l p we k dd g i lly f ed b u f ts t l ty d be se t p rmit l g d tre d y ng t p bl f g i g t mer h t ble ze wh a bl kiddin i q te de tr t t ll t trees th k dd g A m l logg ng h d s ppear d f m ll b t the m llet p t ns T t th t w h mply d g l g n th gr d T t t g he f w de g f ures e ed t ly f r k dd g i all p t f th try They d pt bl t l g t m ll l gs, t t p m ddy t d t w ed gr d Th h pp rt n l t d

pulley th ugh which the cable fr m the tra t r winch is extended to the l gs. Wh en they are fastened to the cable they are pulled up under the arch a d th n dragged with the r front ends ff th gr nd t red ce fr ct n A c awler tr ad arch needed f r l a y l ad and teep r t i dd gr und Wheel d agric lt ral type tra tor re u ed in the E t and So th on firm ground f r mall l g Trac t r kidding d tanc re b t pra tic l c n idera tio s u u lly limit kiddi g t ½ mil For l ger k dd ng a in getti g l gs o t of wide ri r bot t ms l g wag n with wid wh eel t ad or w th rawl r tread a e p lled by tract r

Loading Aft r log h e bee kidded t th t an port t n y tem th y re l aded n h cle r put n wat r f r tran port t the m ll Lo ding methods ra ge f om pulling the ro d l g up skid nt ehicles with a im l r light tr ct rs t h ghly peci lized ra lro d r tr ck l ader E cept fo roll g log ve k ds to wag n r tr k r p h g them int st am l g l di g de ce re des gned t lift log and dep it them n a co ey a e Th r qui s a erh ad pulley block a cable, d powe unit with d um or a draw l ar p ll of t am r tra t r Loading abl ar at ta hed to e hang g f m or gin p l s t guy l ne o are placed at the nds f m able boom The more e satile l aders are self pr p lled w th f ll sw g i g booms which pe m t l d ng truck r c rs from any poi t (F g 2) Stati ary types m t load fr m log once tr t p t Th at t hm t at the end f a lo d ng ble f f tening to l gs may b t gs able loops The m t recent dev l pm nt is boom w th a comp es ed air t ng grab pe ted by the l der th t el minates the hazard s j bs of the t g ho k r d top lo der

Special transportation systems Larg f re t ea req re peci l tran portation sy tem f r haul g l g in deq te of me t upply mill



Fg 2 A lf p p ll d h vy-d ty l g lo d l d g p d f l g ld h f t k h l p t d (Ph t g ph by W sh gt l W k S ill W h gt)

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Logging (forestry)

The first step in lumber manufacture is harvesting trees from forests in the form of logs and deliver ing the logs to a sawmill. *See* LUMBER MANUFAC TURE

Equipment Felling trees selected for cutting is accomplished with hand saws or by power aws The chain type gasoline powered aw with cutting teeth in a chain moving rapidly around the blade is the most widely used (Fig 1) Trunks of felled trees are severed at log length intervals to the point of minimum merchantable size or quality in the top Most log lengths are 12 14 and 16 ft corre ponding to the standard lengths of lumber used in general construction although other lengths are cut for special needs

Logs are skidded hort distances over unim proved terrain to an assembly yard or a loading point on a logging railroad a truck hauling road a winter sled road or a stream in which the logs can be floated or loaded on barges This requires considerable power as do all subsequent steps in logging For example a longleaf pine log 16 ft long and 18 in in diameter weighs 1500 lb Logs are skidded by mobile power units such as a horse or a



Fig 1 A l gg f ll ng a la ge t ee w th a ne ma cha p wer saw (Ph tograph by H m l te Co p)

ll X is Y (un ersal affirmat ve judgm nt)
o X is Y (un versal negat e judgment)
ome X is Y (particular affirmati e judgment)
ome X i n t Y (partic lar negati e judgment)

The three se ten es co tain *altogether three* , S (the subject f the concl i n) P (the cate of the oncl si) nd M (the middle) th t oc r ea h of the premi es P is d th *maj r term*, S the m nor term a d a i e is called maj r or min r cording as it a ns P r S e pect ely It is by virtue of the lle term M hi h occurs n both prem es l tion b t een S nd P may be a erted s the th ee statem nts

N p f sors rich
All hands m men re pr fessors
No handsome me are h

m a syll g sm which M tands f r p ofe ors for rich, d S f r ha dsome men Th p ticu r yll gism s alid (th t s, the nclus n is nseque ce of the prem ses) d hence the alid y of yllogism s ee t be independe t f the uth fals ty of ts conclu Not ce th t the) r p em e, min r premise a d ncl on f ie abo e syllogi m e tatements of type (E) A) (E) espectı ly

The f r fig s of the syllogism are epresented by

(I)	(II)	(III)	(IV)
MP	PM	MP	PM
SM	SM	MS	MS
SP	SP	SP	SP

Ea h ymb l MP SM d so on st nds f r e of th f stat ments (A) (E) (I) (O) fo e am ple, MP might symbol ze the t t m nt No M s P Hence e ch figur has 4 = 64 p s bl forms, and c nsequently th r r 4 4 = 256 p ssible f rm f r a yllogi m The g e t att t g en the yll gi m by l gicians f the M ddle Ag re ulted est bli hing th t o ly 19 of the p ss bl 256 f rms th t yll gi m m ght take are dm ss bl (th t s, y eld l d lu io) It h uld be ted th t th res lt they bt ined rrect pro ded ccept the A ist tel an p ciple that the tatem t All Y s Y' impl s that The e ar Ys. It was also maintain d th t No X is Y im plies th t Some X s not Y" Th s acc ding to ea ly l gic ans un e sals h e t ti l impl cations. Modern l gi i n d t t k th p t f ew This esult i lim n ti g 4 f th 19 adm s ibl f rm (moods) Thr e-syll ble m em n c d er c ed whi h th ow l d ted m der th e mb at o f th tateme t (A) (E) (I) (O) th t e lt d l d yll g ms F r fig (I) th y a B b C l t D rii, F rio f figure (II) C re C m t s F t no B or figur (III) D tisi Feris Dis mis B d D pti, F l pt figu (IV) C lem s F is n, Dim tis B m l p and F s p Th ll tr ti yll g m g e bo e Cel t, fig u e (I) The four m ods that depe d for their va lidity on the cla sic l a sumpt on that uni ersals imply existe ce (and wh ch mu t be el minated if that assumpt n is n t made) are *Dar pti*, *Bam lip Fes po* and *Felapton*

The syllogism is n w of little more th n hi to i cal interest Its lim tations were recognized q te early for it w s cl ar that few of the inference needed in mathematics could be put in yllogistic f rm As rem rked by Hans Reichenb h It i only the c mbination f a logic of functi ns of se eral va able with the logic f pr po itio th t le ds t the full u derstand ng of co versational l nguage s well as of mathematics.

Propositional calculus The unit of the pr po i tional calculus is the propo ition which may be defi ed the meaning f *an indicati e or declarati e* entence Each proposit on h s a truth alue it i either true or false in the classical logic, but may assume other truth values (f r e mple, uncertain) in some of the ew l gics Thus

To err i human

is prop sit n where

Lead us not into temptation

n t a propos tion *It is* con en ent to use letters p q r nd o on to de ote prop sitions P op ition are comb ed by logical connec ti e to form other propo tions Chief among these a e (1) egati n (the negation f a proposition p symbolized by p may be formed verb lly by wr t g It is n t the c e that" belo e p) (2) *conj nction (a binary operat on ymbolized by* or & for example, p q r ad "p and q) (3) disju cti (a bin ry per t on ymb lized by + or f r example p q read p or q") (4) implicati n (a b ary operati ymbol ed by ⊃ or → for ex mple $p \rightarrow q$ read p implies q) (5) equi lence (binary p ati n de t d by ≡ for xample $p \equiv q$ read "p is equi alent i q" mean th t ach p p ition implies the oth r) The p opos t p q ert that both p nd q are true It is imp rt nt t n te th t the d juncti e o alway ed in the cl e en e that i p q rts th t t least ne f the propos ti n p q tr e nd m y be both In ddition the mean ing f impl at in l gic diff m rkedly f m th ord n ry e e of that term The propos t on $p \rightarrow q$ as erts mer ly that it ot the a th t p i tr d q i fal e th t s, n class c l l gi $p \rightarrow q$ mea s th t eithe p i f l e o q is true. Thu ny false pr positi (f r ample Napoleon B aparte w s b rn in the year 1600) impl y prop t wh te er It mpl s, New Y k i a large ty Cleop tra w s q en of Fran e. S mil ly y tru p p siti n mpli d by y pr p it n what e In an mpl ti n $p \rightarrow q$ p is called the ant ed t nd q th co seq t. Th l gi l c n t es tr d d abo e e e ample of log l n t t They r not nd pe dent n t s. Impl ti n m y b defi ed in t rm f g ti nd nj n t n and th i

with daily capacities ranging from 50 000 to several hundred thousand feet per day Standard gage logging railroads with such volumes are practicable They consist of main lines with spurs that ultimately cover all the property Spur spacing depends on the topography and the skidding method but it usually averages about ½ mile Diesel or steam locomotives move empty log cars to the loading area and assemble trains of loaded cars for hauling to the mill Spur tracks are removed after the logs have been loaded out and relaid on new spur locations

At present however most log hauling is by motor trucks ranging from 2–100 tons of gross vehicle weight The larger types are used only on private roads as they far exceed permissible weights for public highways Logs may be transferred from one transport method to another such as from a large truck to a small one for public highway haul or from truck to rail or to water for floating or barging

Where available water transportation is desirable because less power is required to move floating logs When northern freshets in the spring flow from the logging area to rivers that in turn flow to mills stream driving is an economical and effective means of log transport Logs are floated unconfined but are kept from jamming in narrows or stranding on shores by a crew that follows the drive downstream Water from melting snows is held upstream by small dams and released when the drive starts to flush the logs downstream Stream driving can be used only in nonnavigable waters In quiet waters logs can be floated confined within a boom of floating logs fastened end to end that serves as a floating fence In navigable rivers and inland waterways logs are transported fastened together in rafts which are pushed or towed by tugs Barges also can be loaded with logs and then moved by tugs or river craft from loading points to destination The logging operation is completed when the logs are delivered to the mill or a shipping point

Prelogging In western forests of large trees prelogging is sometimes done in which the smaller trees are cut and removed with light tractors or even teams before the large trees are logged by cable systems or by heavy tractors This reduces waste caused by breakage of the smaller tree Integrated logging means the harvesting of several kinds of products from the same stand at about the same time They are removed either prior to subsequent to or at the time of logging and may include poles pulpwood veneer bolts cross ties or other products [A E W]

Bibliography See FOREST AND FORESTRY

Logic

The subject that investigates formulates and establishes principles of valid reasoning

The first attempt to investigate systematically acceptable modes of reasoning was made by Aristotle in whose *Organon* reasoning was recognized as the subject of a special science In that work he formulated three basic laws of thought (1) the law of contradiction (no proposition is both true and false) (2) the law of excluded middle (each proposition is either true or false) and (3) the law of identity (each proposition implies itself) Advanced as his views of logic were it seems doubtful that the idea of axiomatizing it ever occurred to him despite the success of his contemporary Euclid in organizing geometry That aspect of logic which enunciates or establishes valid reasoning (rather than merely investigating it) began with the publication in 1854 of George Boole s *An Investigation of the Laws of Thought* The partly abstract treatment of logic presented in this work initiated the completely abstract developments that were to follow In it the laws of thought are regarded as mere conventions which like the postulates of euclidean geometry might be modified or even rejected to create new logics The only requirement that a new logic must satisfy is the one demanded of every deductive system—consistency Just as different geometries are useful for different purposes a logic that is appropriate in one environment might not be so in another There are a growing number of competent individuals for example who consider that any logic containing Aristotle s law of excluded middle is not suitable for mathematics

This article does not attempt to discuss all of the topics that are traditionally grouped under the term logic Because it is assumed that the reader s principal interest in the subject is to acquaint himself with some of the principles for testing inferences to acquire a knowledge of the use of formal procedures in clarifying arguments and to learn how important parts of logic have in recent years been developed axiomatically the classical theory of the syllogism will be examined and the deductive theory of truth functions (the calculus of propositions) will be presented in some detail For the most part the discussion will be limited to what is called symbolic or mathematical logic for a special set of symbols is employed to exhibit in the clearest way the (at times) complicated logical relations involved The advantages of a thoroughgoing use of a good symbolization are enormous It is by such means that modern logic is able to solve problems that were quite beyond the power of logicians of an earlier time and to render some of the achievements of those logicians almost trivial by comparison

The syllogism The formulation of the syllogism is contained in Aristotle s *Organon* It had a great fascination for medieval logicians for almost all their work centered about ascertaining its valid moods The three characteristic properties of a syllogism are as follows

1 It consists of three statements the third one (conclusion) being a logical consequence of the first two (the premises)

2 Each of the three sentences has one of these forms

establ sh d, and ince functi n is o t ngent if and ly if ts g tio s, elf i con tent f nd only if its n gatio s ta t l gy a d a taut l gy pro ided its gati i lf o t nt, a kn wledge of the chara t r f the n gated f nction ol es the pr b-lem. The meth d makes se of the so-called De M gan formulas $(p \; q) = p \; q' \; (p \; q) = (p \; q')$ in hi h the gn = s gn fi that an e p e i n ppearing o e s de of t m y be epla ed by the e p es o app a ing o the ther s de) nd th Bool n xpan f a t uth fu ct o This i an e pa th t h b ts all of the o juncti e possibil ties f r tr th alu T it a di j ncti n f m tually e lu e (c mpat ble) juncts F r ample, $p \; q$ as m s truth alue T if and nly f the f ct n $(p \; q) \; (p \; q) \; (p \; q)$ does. The l tter f n tio i th B lean expa f $p \; q$ The m thod of n g t on can b ill s tr ted fir t by s d ring th m truth fu ct on $(p \supset q) \supset (q' \supset p')$ an lyzed by the m trix method. W t g

$$[(p \supset q) \supset (q' \supset p')] = (p \supset q) \quad (q \supset p')$$
$$= (p \quad q) \quad (q \quad p')$$
$$= (p \quad q) \quad (p \quad q)$$

and oting that $(p \; q) \; (p \; q)$ a the c j c tio f a p po t n d ts gat s lf co si tent, it f ll s that $[(p \supset q) \supset (q' \supset p)]$ s lf in ist t, and so $(p \supset q) \supset (q' \supset p)$ s tautol gy A co d example u g the Boole n exp n f $p \; q$ i

$$[(p \quad q) \supset q] = (p \quad q) \quad q$$
$$= [(p \quad q) \quad (p \quad q') \quad (p \quad q)] \quad q'$$
$$= p \quad q'$$

Cl arly th truth f t $p \; q'$ s conti ge t, and nseq e tly so s th f tion $(p \; q) \supset q$

Tautologies and forms of argumentation On truth fun ti n T ece arily impl es a ther T p ov d d th *tr th functio* $T \supset T$ ta t l gy For xample $(p \supset q) \supset (q' \supset p)$ a t tol gy and so th truth f t $p \supset q$ es rily m plies the truth fun t n $q \supset p$ O the other h d ther f tho e t o truth f ti is t t l gy and so th impl ti th y hib t e not eces-sary impl ti ns. Valid f rms of g ment ti are based th ti n f ece y impl cat T o h f rm e kn wn t l ss cal l g as (1) *m dus p d po ns* a d (2) *modus tol l d toll ns* The fir t tat th t f n impl ati n $p \supset q$ d ts ntec d t p ar a ert d, th n the conseq t q m y be ssert d th t th t th f cti $(p \supset q)$ p ec a ly mpl q Th s establ hed by p g th t th truth fun t $[(p \supset q) \; p] \supset q$ ta t l gy Th *modus tol l nd t ll ns* f rm f a gum t perm ts th den l f the anteced t f e ted mpl t n wh n ts co seq e t d n ed. Th l dity of th rgu ment t po the t t l gy $[(p \supset q) \; q] \supset p$

A *comm n fallacy* (f llacy f the con equent) is to a ert the antecedent of an impli ation who e c n equ nt l a bee as erted This is not perm s-ible nce the tr th functi n $[(p \supset q) \; q] \supset p$ is t taut logy Although s ch an argument is l gically unw rranted t s frequently n ked in t t ng e p r mentally a hyp the is p F r if q fol lows from p numer us in tances of the alid ty f q re somet mes taken t fur i h tr ng evide ce of the al d ty f p

A t ad ti nal form of a gumentati n known a the d lemma *is an applic tion f m dus pone do p nens o modus t ll ndo tolle s* Consider the *foll w g example*

(1) If I peak the tr th men w ll hate me if I l e, the god will hate me
(2) *I m t eithe speak the truth or lie*
(3) Therefore e ther me will hate me or th gods will hate me

The f rm f th d lemm i as f llows

(1) $(p \supset q) \quad (\supset \;)$
(2) p
(3) $q \quad s$

Th arg me t al d by *m dus p end po ns* f r in e premi e (2) affirm the a tecede t of at le t n of the mplic ti n f premi e (1) at lea t e of th nseq ent *may be asserted* wh h what the cl i n (3) d s

Deductive theory The inte t f th se tion is t ketch the p cedu by which all ta t log es e d d cibl f om a et f just four of them Th s is anal go to wh t i d e n a x mat c geometry n wh h ll the theo em f the geometry are de-d ced f m a le ted et of axi ms o po tulates th t e assum d to be t ue The at of th geom try fully det rm ed by the set f tat ments form ng the po tul tes

Let P d ot a *nempty* b tr ct et, who e el m ts de ted by $p \; q$ and so o re all d p p it (f s ggest e es) nd s ppose P *i cl sed w th pe t t* a ary perati de-ted by ( ) and a b y op r tio de oted by th t if $p \; q$ are a y lem nts f P then p nd $p \; q$ m t b un q e leme ts f P An addi t nal b ary ope t d ot d by $\supset$ *and ead* implie i defined n P

D fi itio If $p \; q$ are el ments f P $p \supset q \equiv_D p \; q$

An e pessio form d by l ments f P and the op at ns ( ) is tr th f ct o f a d nly if t c f rm to the followi g ynt ct l r l (1) $p \; q \; r$ d so n a e t th fu t (2) f $A \; B$ a truth f n t ns th n so e A d $A \; B$ (3) n eq nce f symb ls de tes t th func ti n le it i st ted d g t (1) (2) r le t s pl ble by d fi ti by a t th f ct A bcl f the l s f truth f ti n t t te the l *s of t tolog es It* is a med th t the f ll w g f truth fun t o are ta t l gi (th th po tul t)

true for all of the connectives By use of the symbol $\equiv_D$ to mean is defined it follows for example that

$$p \quad q \equiv_D (p \vee q) \qquad p \supset q \equiv_D p \vee q$$
$$p \equiv q \equiv_D [(p \vee q) \vee (q \vee p)]$$

In fact all the connectives can be defined in terms of one binary operation the so called Scheffer stroke function $p \mid q$ which may be read p is false or q is false Thus

$$p \equiv_D p \mid p \qquad p \quad q \equiv_D (p \mid q) \mid (p \mid q)$$
$$p \vee q \equiv_D (p \mid p) \mid (q \mid q)$$
$$p \supset q \equiv_D [(p \mid p) \mid (p \mid p)] \mid (q \mid q)$$

The logical connectives the letters p q r and so on that stand for propositions (propositional variables) and the parentheses brackets and braces needed for punctuation are formal concepts A propositional function is a combination of concepts formal or nonformal involving at least one variable which is not a proposition but becomes one when all the variables are given specified values Examples are (1) p and q (2) $x + y = 1$ and (3) x is president of the United States Unlike a proposition a propositional function has no truth value On the other hand the statement For every integer x $x + 1 = 0$ is a proposition (not a propositional function) even though it contains a (bound) variable A formal function is a propositional function that contains only formal concepts (for example $[(p \vee q) \quad r] \supset s$) The form of a given proposition is the formal function obtained from it by substituting formal concepts for all nonformal ones Thus p q is the form of the proposition Leonard is happy and the moon is blue Notice that in formalizing the above proposition different propositions were replaced by different propositional variables A truth function is a propositional function in which only propositional variables occur and such that the truth value of each proposition obtained from the function by substituting specific propositions for the variables depends only on the truth values of those propositions Examples are (1) $(p \quad q) \vee r$ (2) Napoleon was a great general and p (where p is a propositional variable) On the other hand Jones stated that p is not a truth function

This article is concerned principally with the class of formal truth functions (that is those containing only formal concepts) and with an important subclass called tautologies [that is those formal truth functions such that every proposition obtained from them by substituting specific values (propositions) for the variables they contain has the truth value T (true)] A truth function is contingent provided it assumes both truth values T and F (false)—here only the classical two valued (Aristotelian logic) truth functions are considered —and self inconsistent provided it has only the value F The character of a truth function is determined when it is shown to be self inconsistent contingent or a tautology

Character of a truth function A truth function may be analyzed by means of a *truth table* or matrix Such tables are made first for the elementary truth functions p $p \vee q$ p q $p \supset q$ as follows

(I)

p	p
T	F
F	T

(II)

p	q	$p \vee q$
T	T	T
T	F	T
F	T	T
F	F	F

(III)

p	q	p q
T	T	T
T	F	F
F	T	F
F	F	F

(IV)

p	q	$p \supset q$
T	T	T
T	F	F
F	T	T
F	F	T

In every table each row of the last column gives that truth value of the function which is determined by those truth values (assigned to the variables) that are entered in the preceding columns of that row For example the second row of table (IV) states that the truth function $p \supset q$ has value F (that is is false) when p has value T (that is is true) and q has value F Since all logical connectives used in the logic of propositions are expressible in terms of negation and disjunction only tables (I) and (II) are really essential but tables (III) and (IV) are convenient when analyzing complicated truth functions Although the character of any truth function may be determined by constructing its truth table the method is tedious when the function contains a large number of variables since the truth table of a truth function of n variables has 2^n rows As an example the character of the truth function $(p \supset q) \supset (q \supset p)$ may be determined Using tables (I) and (IV) the truth table of the function is found to be

p	q	p	q	$p \supset q$	$q \supset p$	$(p \supset q) \supset (q \supset p)$
T	T	F	F	T	T	T
T	F	F	T	F	F	T
F	T	T	F	T	T	T
F	F	T	T	T	T	T

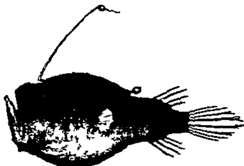
Since every entry in the last column is T the function $(p \supset q) \supset (q \supset p)$ is seen to be a tautology It may also be observed that in each row the entries in columns 5 and 6 are the same that is for any given values of p and q the functions $p \supset q$ and $q \supset p$ assume the same truth value Hence $(q \supset p) \supset (p \supset q)$ and the two functions are logically equivalent The principle embodied in this equivalence (the law of contraposition) is often used in mathematic

Another device for ascertaining the character of a truth function is the method of negation It sometimes happens that the character of the function obtained by negating a given function can be easily

birds the legs, being set far back, are useful for swimming b t m ke the b rds quite clumsy on land. They p e fish underwater w mming with the feet only Loons are Holarctic in d stribution all four pecies oc in North Amer ca three of them in the United States. Loo s are beautiful in teresting birds, b t they are be t known for their call, h h h s been de cr bed as a weird sort of la ght r See GA IIFORMES [J D.B.]

Lophuformes

The anglerfi hes a d the relati es Th s highly modified der f a t nopterygian fishe also kn as the Ped lati was derived from perci form stock t least a early as Eocene time The first d sal fin red ced to few flexible rays, of hich the fir t is pla ed on top of the head and bears t rminal bulb or tassel and fu ctions as a fi h g lu e The ep otic are large and me t behi d the s p aoccipital Th re are o ribs or epipleurals a d the gill openi g s mall and placed far b ck. Pelvi fins, if p ese t, are th acic and the pectoral girdle is n t bly mod fied



Anglerfish Crypt pso l gth t 4 ft (Aft G B G d d T H B O *Ichthy l gy U S Natl. Muse m Sp B II 2 1895*)

There a 3 s b rde s 15 f mili s, 50 g ner and bo t 160 kn wn pe ies All e m r e M t pecies inhabit deep e or tr p c l h w ters the l tte f rms re omm ly sedent y n habit Luminescent gans m y be p e e t d n me deep-s a pec es th male a e dw fed nd t tached as ect p ra t s n the females See Ac TI OPTERYGII.

[R M B]

Bibliog phy E. B rt l n *Th Ce ati d Fish Ont ge y T x nomy Distributio d B l gy* Dana R pt. 39 1951

Lophophore

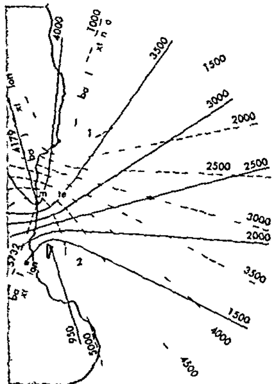
A f ld (kin bear g cil ated t ntacl s It urs in Bry zoa (E t pr ta and E t p o t) Bra hio poda, nd Ph d It i c ular t h s sh e h ped. I some gr p it nc cles only the m uth in th r gr p both mouth d s It i fl bl nd is p ded w th muscl ti su nd n rv tru ks. I the E t procta t can o t act l ke a phin t th i t cl whil n th Ect p octa both t and the tentacles ca be retracted into the body ca ity Tentacle number in bryozoans with a circular loph phore seems less variable than in bryozoans with a hor eshoe- haped lophophore The lophophore serves as a tr ugh for the food beari g stream [M D RO]

Loran

A navig ti n system fr m wh ch hyperbolic lines of positi n are determin d by mea ring the d f fere ce in time of arrival f pul es from widely paced syn hron zed tran mitti g stat on Th in tersection of two such lines of positi n gives a nav gati nal fix or locat n Loran is used by com merc al and mil tary ships and aircraft The name is deri ed fr m LOng RAnge Na gati n

Developed during World War II to pro ide ac urate na igat onal inf rmat on o er a wide area Lo an s nighttime service co erag was 63 000 000 squa e mile nd ts dayt me cove age about 15 000 000 quare miles by Augu t, 1945

Standard loran Standard l ran transmitters send out t ains f p lses about 50 micr econds wide at a r currence rate at or nea 25 pul es per eco d (pps) A seco d ba c rate is 33⅓ pps The p k pow r f a tran m tter is 100 kilowatt o m re altho gh the a er ge power is on derably le s. Rad fr quencies employed are in the rder of 2 megacycles



Fg 1 Tw l f p t ge t d by ma te d l t t p o d a fi F f th n g t Da h d l e a g e t d by m t d l o 1 l d l by m t d l o 2 Th lo d g t th l p t d l y t m m ds.

P1	$(p \vee p) \supset p$
P2	$q \supset (p \vee q)$
P3	$(p \vee q) \supset (q \vee p)$
P4	$(q \supset r) \supset [(p \vee q) \supset (p \vee r)]$

These simple tautologies were selected by Alfred North Whitehead and Bertrand Russell in their monumental work *Principia Mathematica* as the basic set from which all tautologies can be derived They had an additional postulate

P5 $[p \vee (q \vee r)] \supset [q \vee (p \vee r)]$

that was later shown by Paul Bernays to be deducible from the first four postulates and hence may be deleted as a postulate It is interesting to note that none of the three Aristotelian principles (the laws of identity contradiction and excluded middle) are in this basic set They are all deduced as theorems

Before any theorems can be deduced there must be available rules that allow one to go from one step in a proof to another Among such rules are those of formal substitution according to which (1) any truth function may be substituted for any of the variables occurring in a postulate or theorem provided the substitution is carried out completely and (2) any expression may be replaced by one definitionally identical Among the rules of formal assertion are (1) the *principle of inference* (that is if P and $P \supset Q$ are postulates or proved theorems then Q is a theorem) and (2) the *principle of adjunction* (that is if P Q are postulates or theorems then P Q is a theorem)

It was proved by E L Post that postulates P1-P4 are consistent that is it is impossible to deduce from them truth functions X and X He also proved that the four postulates form an independent set that is no one of the postulates can be deduced from the others

Non Aristotelian logics In these logics the principle of the excluded middle (that is each proposition is either true or false) is not valid There are then at least three truth values possible for a proposition and for this reason such logics are known as many valued In a many valued logic the *reductio ad absurdum* procedure that is so frequently used in mathematics is much less effective than it is in the two valued classical logic for if it has been shown that a given proposition is not false one may not conclude (as is permissible in Aristotelian logic) that the proposition is true The Aristotelian tautology (p) ■ p is not a tautology in a logic with at least three truth values Doubts that the classical logic is an appropriate one to use in mathematics stem from the modern view that the concepts and relationships dealt with in mathematics have no real existence in the external world It would seem to follow that the a priori nature of true and false then disappears and with it the law of excluded middle If "true" be interpreted in mathematics to mean provable and a proposition be called false provided its negation is provable then the law of excluded middle is demonstrably false since it has been shown that mathematics contains propositions p such that neither p nor its negation p is provable The intuitionistic school of the Dutch mathematician L E J Brouwer rejects the excluded middle law and it forms no part of the logic of that school formulated by A Heyting See BOOLEAN ALGEBRA GEOMETRY EUCLIDEAN MATHEMATICAL NOTATION CONTEMPORARY MATHEMATICS SCIENCE SCIENTIFIC METHODS [L M BL]

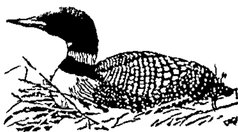
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Longitude, astronomical

Longitude determined by astronomical observations as distinguished from geographic longitude which is that shown on a map Astronomical longitudes are determined by the definition that the longitude from Greenwich is identical with the difference between Greenwich mean time and local mean time Greenwich mean time is ascertained by the reception of radio time signals Local mean time is determined by observing either meridian transits of celestial objects or their altitudes near the prime vertical In either case the angle between the line of sight and the direction of gravity is measured the direction of gravity being established with the aid of a spirit level a liquid surface or observation of the horizon corrected for the elevation of the observer The direction of gravity is however not in general precisely toward the axis of rotation of Earth as it would be if Earth were concentrically homogeneous The deviations are called deflections of the vertical they commonly amount to some seconds of arc occasionally reach a minute of arc and vary from place to place A map constructed exclusively from astronomical observations would in consequence be distorted by amounts varying from a few hundred feet to more than a mile See GEODESY [C M C]

Loon

Any of four species of aquatic birds of the genus *Gavia* comprising the family Gaviidae and the order Gaviiformes Loons are rather large diving



Loon Gavia immer length 32 in (E L Palmer Field book of Natural History McGraw Hill 1949)

birds the l gs, being set far back, are useful for *imming but* make the bird qu te clumsy on land. They purs e fi h nderw ter swimm ng w th the feet o ly Loo s a e H larct c n di tr bution all four pecies occur i North Ameri a three of them in the U ted St te Loons are be ut ful, in teresting birds, but they *are best kn wn f r their* ll, hi h has been des ribed a a weird sort of la ghter S GAVIIFORMES. [J D B.]

Lophiiformes

The anglerfi hes and their relati es This h ghly mod fied der of ctin pt rygian fish s also known as the Pedi lat w s deri ed from perci f rm tock t le t early s Eocene time The first d al fin is reduced to a few flexible rays of hi h the first is placed on top f the head and bears *t rminal bulb or t s el and f ct ns as a* fishing l e The ep tic are larg and meet beh nd the p oc pital There re no ribs o ep pleurals d the gill pe ing small and pl ced far back. Pelvic fi s, if p ent re th ac c, and the pectoal girdle s ot bly modifi d.

Angl rfish *Crypt p* ; l gth t 4 ft (Aft G B. Good d T H B O *I hthy l gy U.S N tl. M se m Sp* B ll 2 1895)

There are 3 ub d rs 15 f milie 50 g a and bo t 160 k wn pec es All a e m ne. M t pecies inh b t d p e *trop c* l h e w t the latt form ar comm ly ed t ry in h b t Lum n sc t rg m y b p t a d n me deep-se spec s the male a dw rfed d t t hed as e topar tes th fem les. S Ac TI OPTERYGII.

[R.M B]

B bliog phy E. Bertel e *Th C an id F h s Ont ge y Tax nomy Distributio and Biol gy* Dan Rept. 39 1951

Lophophore

A f ld f k b g c li ted te tacles It oc r in Bry zo (Ect p octa d E t p ct) B h o-pod d Pho d a. It circular t h esh e-shaped. I some gr ps t cir les only the m th in ther gr ps, both m uth d a It fl ble tr ks. I the E top octa it ca t a t l k th t o th te t les whil n the Ectop oct both *it and the tentacle can be retra ted int the* body ca ity Tentacle number in bryozo ns with a c rcular lophopho e eems less variable than in *bryozoans with a h rseshoe-shaped* lophophore. The l phopho e serve as a trough for the food beari g stream [M D RO]

Loran

A na igati n sy tem from which hyperbolic li es f position a e d termined by measur ng the dif ference in time f rri al f pulses fr m widely spaced ynchro ized tran *mitting station The in* ters ti n f two such lines of po tion g es a na ig tio al fix r l cat on Loran i us d by com *merc al d mil tary sh ps and ircraft The name* derived fr m LOng RAnge Navi gation

De eloped during World War II t pr ide ac urate n ig tio al nformat n er a wide rea Loran s n ghttime servi e co erage was 63 000 000 quare m le and its dayt me co erage abo t 15 000 000 square miles by August 1945

Standard loran Standard l ran tran mitters end o t t ins f pulses about 50 mic o ec ds wide at a recurren rate at r ne r 25 p lse per e ond (pps) A econd ba c rat is 33⅓ pp The *peak power of a t n m tter i 100 kilow tt* or m e ltho gh the a erage powe is c iderably less Rad o f equen es employed are in the o d r of 2 megacy les

F g 1 Tw l f po i g t d by m st d l t t p d fi F f th g t Do h d l g t d by m t d l l d l by m t d l 2 Th f d g t th l p t d loy t m m se d

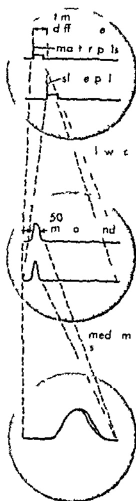


Fig. 2. Pulses adjusted to sit on pedestals are electronically magnified and leading edges matched. Exact time delay is shown by markers or counter settings.

One station of a pair is designated a master and normally sends an uninterrupted series of pulses. The second station, located some 200–300 nautical miles away, is called a slave and must maintain its radio frequency and pulse recurrence rate exactly in accord with those of the master. In addition, the slave must maintain a fixed time difference (usually 1000 microseconds) between its reception of the master signal and its transmission of the slave pulse. If either the master or slave operator notice a change in these relationships, the operator periodically interrupts (blinks) his signal until proper adjustments have been made. The blinking signal warns navigators of possible error.

Because two pairs of loran signals are necessary to obtain a navigational fix at the intersection of two lines of position, it is economical to operate a loran chain in groups of three stations (triplet). The center station of a triplet acts as the master for the other two and transmits at two pulse recurrence rates, for example, 25 and 25⅙ pps.

The loran receiving equipment used by the navigator comprises a fixed tuned receiver and an indicator that includes a cathode-ray oscilloscope. A 100-kilocycle crystal clock with good short-term stability is the basis of sweep generating and divider circuits. The crystal circuit can be tuned over a narrow frequency range sufficient to adjust to small changes at the transmitter or receiver. A multicontact switch in the divider circuits provides synchronism of the sweep circuits to each of the pulse rates assigned the various stations of a chain. By this means a number of transmitting stations can operate on the same radio frequency. The individual pairs of stations are identified by their pulse modulation. The stations are identified as master or slave by causing the master pulse to arrive before the slave pulse. The unique time delay between arrival of master and slave pulses at the navigator's equipment is the desired position information.

In use the master pulse, appearing as a vertical line and identified by arriving first, is set upon a pedestal on the upper trace of a slow sweep oscilloscope pattern. A movable pedestal on the lower trace is placed beneath the slave pulse. Because of their different recurrence rate, all other pulses received appear to move relative to the desired pair.

A fast sweep shows the form of the pulses. The pedestal control permits superposition of the leading edges of the pulses. Time markers generated by the crystal clock and the dividers show the time delay, accurate to within a microsecond, between master and slave pulses. This delay is shown on the corresponding line of position on a chart or map.

A similar observation on the other pair of signals of the triplet provides a second delay time, also shown as a numbered line on the chart. The time required for such an observation is generally less than 3 minutes. In aircraft navigation it is customary to take a second reading on the first pair of stations and to average the two for greater accuracy, because of the distance traveled while taking the readings.

Some loran indicators are direct reading; that is, numbered dials or counters show the delay automatically after the pulses have been superimposed.

The distance at which reliable loran fixes are generally obtained is about 800 nautical miles over water from the pair of transmitting stations during

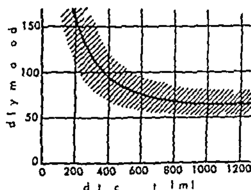
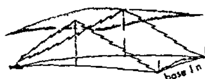


Fig. 3. Sky-wave delay as a function of distance shows amount that sky wave lags behind ground wave. Shaded area shows limits of variation. (From J. A. Pierce, A. A. McKenzie, and R. H. Woodward, Loran, McGraw-Hill, 1948)



( )

(b)

Fg 4 Sky-w fl h s. ( ) A mpl y d t te d ghttm se (b) T t d b l s l n From J A P e A A McK d R H W d- rd Lo M G w-H ll 1948)

dayt me and abo t 1500 miles at night. Daytime d tance o r l nd ı 100-250 m les. A cur cy aries o e the rv ce ar a b t g n r lly better th n th t fr m elestial fix The m nımum err r f tand d lo an abo t 500 ft. At dı ta e f 1000 miles fix cc ate t within 10 m le should be poss ble.

Th gr te ghttım co erage s due t the remarkable tab lıty at n ght f the E l y of the ıo phe e. Th ı some lo f ccu a y sın e p lses flected f om th on phe e a d layed l ıı to gr u d wa es a d thı delay n t every h r th same. Th ky w e del y dec eases as th d tanc f tr n mı n ınc ea e bec m g ne ly c n tant t 1000 mil or m e S RADIO-W VE PROPAGATION

Ss loran. Th ky w e-syn h n zed adapt t on f l an as dev l ped fo the RAF n n ght a d over Germany ı the fi al x m nth f th E ropean phase f W ld Wa II The a age rr f fi m 22,000 sort was report d le th n 2 miles.

In this y tem yn h zat b twe n m ster and f e t t n s ffe t d u ng E laye flec tıons r th th n grou d wa e s g l The l ng b e l es p de an re ı g met l a ur cy th t mp n ates f oth r o s f e ro lar atı n ph e height e ult n an av e ge err of bout 8 μ ec f a gle re d g A mınım m rr f 0 9 na t al m l ıs th s tablish d h n the g tor s loc t d t th ı te secti n of t b lı es ng t ght ngle

D ıng ı o pheri t rms la g arı tions th effec e height f tl e E l ye m y ause ma m m er s f fi f 5-6 mıl but th occu n t mo than 1% f th time S ı f t ry n ghtt m ya hr zat n b m ta ed abo t 99 8% f the tı e, ex ept h e poı t of fl ct n a e f fected by al ph om S IO OSPHERE

Lf loran. I t al p r m tal ı at of th s lo f q y (lf) v rı t of th l n t h que wa begun ın 1945 using a frequency of 180 k locy les (kc) Further experiment ha e been car ıed out at r near 100 kc

Beca se l ng r pul es (about 300 mı rosec nd) are requ red for lf l r n the read ng error even at sh rt d tances ı likely to be four times greater th n for tanda d loran (about 4 mı roseconds) Spectrum ec nomy a d the d fficulties of rad ating hort pul s at 100 kc n ce ar ly make the tıming ccuracy less

The use of low radıo frequ ncies permits l ng b lı e (2 3 time the ba e l ne for standard lora) to be u ed and therefore ıncreases th geom trı al acc r cy of the y tem Average l ne-of po ıt n r r f r a sy tem empl yı g a 600-m le ba e lıne r ed between plus r minus 3 mile du ng s mmer day or night at dı tan e of 500 m le t pl s or m nus 6 miles *(d y) and plus or* mı u 16 miles (n ght) at a d sta ce f *000 nau* tical miles It has been est mated that the sy tem might have an a erage error f one-q arter of a m le ın the best area

An mp rt nt fe t re po s bl n lf l r n ıs cy l mat h ng whereby the phase of ındı ıdual radıo-frequency cycles of a p r f pulses ıs c m p red to p oduce a high accu acy f fix Test of the exp r m ntal v tem g e an erag fine f p ıtıo rror f 160 ft on st tı ns ı50 m les dıst nt.

An nh ent ad ntage ın lf lor n ıs the ange po sible r land where a d stance of 1000 m le day r n ght. an be attaı ed Th s d ta ce ıs om p ble t the a g r wat r

Var u hype bolı na gatı sy tems re known a Lo an A r st nda d lo an Loran B or med um dı ta e precı on l r n a d Lo an C r Cyta

Lo a ha the me ad ant ge as any syst m whı h r qu es no transm f d o-f q ency ene gy from th na g ıı g r ft. *Becau e no c m* mu c t n ı eeded with the avıg to th system d s not s tu at nd ny numbe of veh cles can t.

The c mputat s equ ed fo p oduc ng h rts and t bles ru to m ny m n ho s b t nce they h be n made the c t pread o er man observations the eby ed c g labor t me, and ex pe e p r n gat o l fix [A A M]

B bl g phy J S Hall *Rad A ds t Nat g ıı* 1947 J A Pıe ce, A. A M Kenzie, a d R H Woodw rd *Lo* 1948 P C. S drett *Fl ct on A gation F g eerı g* 1958

Lorentz transformations

Th family of mathematıc l t nsf rmat used n the pe l theory f el t ty to r late th pa d time a ables f u ıf mly m ng (n t al) r fer nc y tem Th y we d sc *red* part by H A Lo ent d rı g hı tud f matte m g ın an el t m g tı field d were f rmu lat d mo e compl tely by H Po a d by Al be t E n t n If S d S e tw rtıal ef nc f m w th pa e-tım oord t s $(x y ,t)$ and

$(x' y' z' t)$ respectively the equations connecting these variables have the form $(x^0 = ct \quad x = x \quad x^2 = y \quad x^3 = z)$

$$x^{\alpha} = \sum_{\beta=0}^{3} L_{\beta} \; (x^{\beta} - a^{\beta}) \qquad (\alpha = 0 \; 1 \; 2 \; 3)$$

where $a^0 \; a^1 \; a^2 \; a^3$ are arbitrary real constants Forming the two real matrices

$$L = \begin{bmatrix} L_0{}^0 & L_1{}^0 & L_2{}^0 & L_3{}^0 \\ L_0{}^1 & L_1{}^1 & L_2{}^1 & L_3{}^1 \\ L_0{}^2 & L_1{}^2 & L_2{}^2 & L_3{}^2 \\ L_0{}^3 & L_1{}^3 & L_2{}^3 & L_3{}^3 \end{bmatrix}$$

$$\eta = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

the matrix L is subject to the condition

$$L^{-1} = \eta L_t \eta$$

where L and L are the inverse and transposed matrices of L

The Lorentz transformation group is composed of four classes of transformations which can be organized as indicated in the following table depending on the algebraic signs of the pivotal element $L_0{}^0$ of the matrix L and the determinant of L which is designated by $D(L)$ Positive signs are indicated by + and negative signs by − in the table

Classes of Lo entz transformat ons

	L	$D(L)$
P pe	+	+
Imp pe	+	−
	−	+
	−	−

The improper Lorentz transformations involve changes of sign (reflections) of the space coordinates the time coordinate or both For additional discussion of improper Lorentz transformations *see* SPACE TIME

The proper Lorentz transformations form a 10-parameter group which can be generated from translations of the space time coordinates rotations of the space reference frame and transformations to uniformly moving systems *See* RELATIVITY [E L HI]

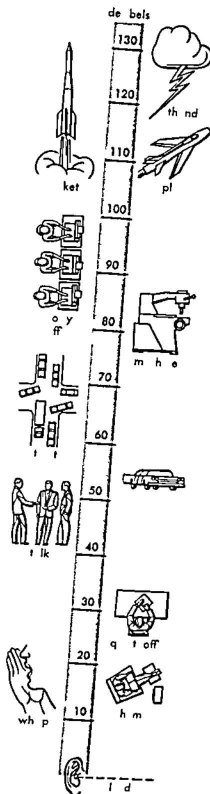
Bibliography R Brauer and H Weyl *Am J Math* 57 425 1935 F D Murnaghan *The Theo y of Group Representations* 1938

Loschmidt s number

The number of molecules in 1 ml of a perfect gas at 1 atm pressure and 0 C It is found by dividing the Avogadro number by the normal molar volume or normal gram molecular volume in milliliters Its value is $(2\,68709 \pm 0\,00009) \times 10^{\,9}$/per ml *See* AVOGADRO NUMBER MOLAR VOLUME [T C W]

Loudness

The psychological property of sound characterized by strength or weakness It varies most directly with the physical intensity of sound increa ing as intensity is increased and decreasing as intensity is decreased Loudness also varies with frequency of sound waves Tones of very low and very high frequencies require much more intensity than tho e



F g 1 A dec b l cale show g el t nte t e f comm n sou ds

140
120
110 ph
100
80 ph
80
60
40 ph
40
d bl ty
20
(0 so)
0 ph
lo d
0
100
1000
10 000
f q cy p

Fig 2 Th d fi t l t h p b tw l d s le l pho d te ty l l d b ls.

in the middle a ge f 1000–5000 ycl per c ond (cps) in o der t be pe ei ed qually lo d

Lo dness measur m t is sign ficant i all te h ucal and theo etic l m s rem nt of h a ng pe- cially in se n e t gat on and co t ol nal i f ommunic ti n tr m tat on nd n sy t m tic study of the me ns by wh ch the ditory mechani m resol e d fferen e n sou d nte ty

Decibel In pr ct cal work deali g w th sound the tre gth l sou d i u ally pre ed in decibel (db) unit of phy cal i tens ty o s u d p es e level. D b l ar relat e unt exp ess- g a ti betwee gi en o nd nt n ty nd a ref ce so d A b l s the l g rithm to the b e 10 f the ati f a s u d f g en nt n ity t the r f ten ity a d c bel i o e-te th f a bel 0 en ent r f re e so nd whi h w dely used as a tanda d fo a d ibel scale s the und pressure f a t ne f 1000 p (0 0002 dy es/ m) h h j t b rely he rd by the m l ear Th s l is somet mes c ll d ero lo dn A ound 10 times as t e n e e gy has a al e f 10 db o e 100 t m s as i t n 20 db Th int ty level l som o dnary o d s h wn n F g l Ve y l d th de t 120 db wo ld be l 000 000 000 000 times as nten s a bar ly p ept bl sou d f 1000 ps.

Phon Dec b ls are s ful u its f phy l n ten ty b t d not sp fy th psy h l gi l l d nes f sound A c l f l ud e lev l b d n t s ty lev l, u es a unt alled th phon The lo dnes lev l f ton s the i t t le l of the 1000 p t to wh h t so d qual loud e s Thu a 1000 ps tone at 40 db h a lo d e f 40 phon Oth frequ es wh h r j dged equ l n lo d ess lso ha l dn le el f 40 phons alth gh th nte ty le el may b o ide bly h gh r tha 40 db F gu e 2 h w the f tionsh p bet een decib l d ph s t rm f ses al qu l l d c t The l w t c n p e nt the ab l te th e h ld a l d ess lev l f 0 ph n It h ld be n t d th t eq l l d ess t u s at p g e ly h gh l ud es l l bec me m e d m e fl tte ed ut I other w ds the h gher the inten ty the more clo ely d es lo d e level corre p nd with inten sity l el through ut the range of frequencies

Sones Phons are ba ed on psychological judg ments f equal l udne but do n t co t t te a true lo d e s cale That i sound of 80 phons i not nece arily twi e as lo d as a o nd of 40 ph ns To btain a lo d e s c le ba ed n equal psy h l gical i t rvals b erver were a ked to ad j st ounds to be twice a loud " or half a loud a referen e sound or to be midway between two refer ce so ds. S ch a scale ha b en e tabl hed f r un ts called on One sone i defined s the l udne f a 1000 cps t ne at 40 db (Fig) If both loudne and ten ity are r pre ented l ga thmic lly l udne s increa es ery rapidly at l w inten iti less and le rap dly at high r inten tie

The l dne s of c mplex ound ar es w th the distribution of their components alo g the fre- quency ange If the c mpone ts a e ffici tly separ ted the loudne s of the t tal c mpl x nd i equal to the sum of the loudnesses f the c m pon nts p e ented eparately If the comp nents are not widely sep ated the t tal lo dne i le than the s m of the omp ent lo dne es Th i app rently d e to the f t that r gio s of cochlear o neu al a t ty et p by the component o e lap wh n th y are cl t geth r *See* AUDIO IETRY DEAFNESS HEARING [K U.S]

Bibl ogr phy I J H r h *The M s reme t of Hearn g* 1952

Loudspeaker

A dev e th t nv rts ele tric l gn l ene gy into a o tic l e e gy wh ch t r d tes nt a bounded pa e uch as r m r i to outd r p e Th e e t al ha cter tic f the ign l energy m t be p e rved n the ergy c n i n p oces The sh rter term sp k i u ed when it w ll n t be co fu d w th a speak ng per n The term u it in horn n t i ppl ed t de ces c mpri g a m tor nd d ph agm b t lack ng the a u tic le m nt u h a a h r to mplete the sp aker The t rm p k r y tem i orm lly r rved f a pl r l ty f peake t nd the o iated ac - so es, h rns cabi ts and le t c l etw k re- q r d fo an nt gr ted yst m

Requirements for speech and music Th two m t mp rt nt r ble i a und wa a e pres u e a d the f equ cy f the p s u e ltern t ons be a s the ud t ry r p e of th li tener is mo t cl ely r lated t the a bl s. Th pprox mat d t ry l mit f the ea ar hown n F g l The l m t n rmo s a ge freq n es d ffering by a fa tor of 10^3 pres r d ffe ng by fa to f 10 nd i ten t s (powe) d ffering by a f t f 10 Fortu ately unds wh h a e mmonly r p odu d h a m c d peech e the m re l m ted r g s l h w n F g l The d f r ep od i g e n the ang s is further m d fi d by p ycho c t c fa to s and o S HEARING

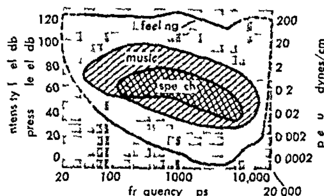


Fig 1 App ox mate auditory l m ts of the ear Shaded areas i d cate the intensity and pressu e levels found n peech and mus c Standard reference levels a e 10 ⁶ watt/cm² intens ty (plane wave) and 0 0002 dyne/cm pres u e

Tests have shown that frequency ranges of 80–11 000 cps for music and 150–8000 cps for speech if uniform throughout the listening area give high quality reproduction in an otherwi e distor tionless system The pres ure range requirements are set primarily by listener preference The lis tener is seldom interested in hearing a wanted sound in the presence of a competing unwanted sound (by definition noise) of the same pressure Noise therefore commonly limits the minimum pressure of interest particularly in music reproduc tion

Alternati ely the requirements of the speaker may be considered from the viewpoint of the com plete system de igner who normally desires a speaker which does not noticeably narrow the fre quency bandwidth lower the signal to noise ratio or increase the distortion of the system Probably the most important requirement is that the speaker not introduce noises that are clearly spurious and unrelated to the signal such as rattles and buzzes Some physical performance characteristics can be adequately measured and specified others cannot however and a thorough listening test i an essen tial part of any speaker testing program The final judge of the value and adequacy of the speaker (and system) is the ear of the ultimate user See PSYCHOACOUSTICS SOUND REPRODUCTION SYSTEMS ELECTRICAL

Physical performance characteristics Because of the importance of pressure and frequency in hearing the loudspeaker output in terms of these variables is also important

Pressure response Measured at a specified fre quency the pressure re ponse is the sound pres sure in dynes/cm at a designated location with re pect to the speaker per volt input The pressure is commonly measured under actual or simulated outdoor free field conditions in the absence of un intended reflecting urfaces

Pressure response–frequency characteristic Commonly called simply the frequency response this is the pressure response obtained as the test signal frequency is varied slowly over the audible frequency range (20–20 000 cps) The response characteristic should be free of abrupt changes which are accompanied by transient and some times nonlinear distortion A smooth curve al o simplifies electrical equalization or compensation

Directional characteristics The e are deter mined by measuring the pressure response at a sufficient number of points in the intended li ten ing region and at a sufficient number of frequen cies to predict the frequency response at any listener s po ition with the desired precision The most common practice is to obtain frequency re sponse characteristics at a few points equidistant from the speaker but subtending different angles with the principal axis of the speaker On axis curves are usually published becau e the pressure is normally a maximum particularly at high fre quencies where focusing is marked In typical en vironments the response characteristic at 30 is much more useful for predicting the average re sponse throughout the listening region In use the speaker is positioned and oriented to give the most favorable average pressure response–frequency characteristic in the listening region See SOUND

Distortion Although distortion may be more broadly defined loudspeaker distortion is com monly limited to nonlinear transient and fre quency modulation distortion

Nonlinear distortion arise from lack of propor tionality between the electrical input and acous tical output signal with a sustained (steady state) input signal With a sinusoidal input integral multiples of the fundamental frequency or har monics are generated If two or more sinusoidal signals are applied the nonlinearity gives rise to interaction between the two or intermodulation distortion resulting in the generation of harmonics and the sum and difference frequencies of the fun damentals and harmonics

Transient distortion arises from the inability of the peaker to follow instantaneously irregular changes in the wave shape of the electrical signal Sharp peaks and valleys in the pressure frequency response curve are to be avoided becau e they indicate the presence of inadequately damped re o nances which give rise to this distortion The e poorly damped resonances color the reproduction and when present at high frequencies they are detected as a ringing sound

Frequency modulation of a signal is the altera tion or modulation of its apparent frequency by a second or modulating signal It occurs when the radiating diaphragm is vibrated toward and away from the listener by the modulating signal The velocity component with respect to the li tener produces a Doppler shift See DOPPLER EFFECT

Electrical speake impedance This is the com plex ratio of the applied sinusoidal voltage across the signal terminals to the resulting current The normal or loaded impedance Z_n the free r un loaded impedance Z_f and the blocked impeda ce Z_b correspond re pecti ely to operati n with tl

ormal aco tic lo d in a acuum and with the ot nd d phragm blocked r mmob lized

F j t The f r fa t r *M* of the motor 1) the c mplex r ti f the f ce equired to lock r imm b li e th mot r to tl e g al inp t current to the m to nd (2) the c mplex ratio of the res lting p n r t oltage to the el city f th mechan al sy tem I a mo ing c l speaker the fi t q ntity q ls *Bl* wh *B* is th e age c d l fl x d ty thr gh the c nductor nd *l* is th du t r length The nd q a tity eq ls *Bl* Wh o tent t ar sed the quant ties b th me magn t de b t oppo te ign ind cat g a t ecipro al latio h p th t is *M* −*M*

The ormal mped c f a peake s

$$Z_N = Z_b + \frac{M^2}{Z_m} \qquad (1)$$

h *Z* the t tal effecti e m han l m pedan of th m g y tem in l ding di phr gm and a l d I a m ng-c il peake M^2 *B*²*l* In t o- lectr de lectr tat c p ker *M* −(*E* / *d*) wh e E_0 i th dc b as lt ge, d_0 the er g bi ed l ct de p r t o and ? tim f q e y Th ec nd t rm n the ght hand de f Eq (1) ar e fr m m ti n of th m g y tem d ll d the l aded r no alm t al mped e

Effic ncy Th peak r effi ency i the at of th eful t c e gy utput to the le t ic l gn l e e gy i p t The y tem a ail ble p w ff e y the t of the f l ac u t en gy tp t t th e gy the g l sy tem will supply t de g at d i t n e.

Th ac u t c tp t may b obt i d by det mining th t ty (see b l w) f th sou d wa a n mber f q id t t po t f m the pe ker nd f e field (tdoo) ond ti n and mm g t l gr ting th te ty n all d r t n The d t h uld be se e l time the m x mum d men n l th pe k nd a ffi i t n mb of po t m t be ed t p rm t c ur te i terp la t and t g t Becau e sou d inte ty me ter are ra ly l bl the pre re me su ed l d th bo t t c dit n b t ot i ormal l ing room th t ty *I* the d t o of *p p g t*

$$I = p^2/\rho c = 2.42 \times 10^{-} p \text{ watt/ m} \qquad (2)$$

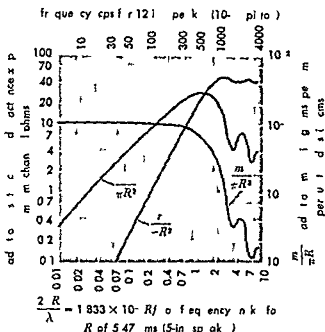
h r p the p e re in dy e /cm ρc th har ct tic imp d e (h r t e) f a r ρ th d ty f dry 0 0012 g/ml a d c the loc ty f p p t n f th so d w e 34,290 m sec both t 20 C d 60 mm Hg p e re Th l t ic l p t p we the m p t rrent squar d tim s the t e p rt f th lectr l rm l mp d n *Se* S UND I TE IT Sou D PRE SURE

Speak pow at g (*i put*) Unl therw s ted, th th m mum utp t p w t g f its inte ded a c ated mplifier when the ign l s spee h and m sic a d the ampl fier is op ated n it l near (ndi torted) rated regi n U der the e c nditio s the a erage p er o 15 ec i tervals will b 1–2% and tl maxim m pow r t any e freq ncy er a ? ec interval will be 10–15% of the r ted lue As an e ample 10-w tt peaker is i tended to w rk with a normally ope ated 10-watt mplifi r with pee h and m ic input *It is not expected to perate c ntinu u ly* w th 10 watt input at all frequ ncie in it t ans m tted f eque cy b d w thout di t rtion or fail ure

Speaker types Speakers ar comm nly cla si fied by terms wh ch d cribe the r three mporta t f nctio l p ts the m t r d aph agm and acous tic r di t on ontr lling element The mot r co rt ele trical energy into m han c l nergy a d c ple the elect cal s gnal so ce omm nly a amplifier to the d aphr gm C mm m t r type a e m i g co duct (p in pally m i g co l dy ami r ely ribb n cond ctor) a d ele tro tat M i g c du t peakers are th e in which the mech nic l f ces re ult f m magnet c ea ti n between th field of the ur ent n a m ng nd t r and a te dy mag eti fi ld In a mo ing l peake the nd ct is n the form f a il ond ct ely o e t d t a ou ce f l ctri al ergy nd me h n ally att ched to th d a phr gm An el t tatic peaker is ne in which the m ch ni l d pl ceme t are prod c d by th cti of elect t t fi ld Other m t r type wh ch n lud th m g ti armat re p e mati p ezo lect i and n c type e di u sed in the *efer nc l ted i th bibliography*

Th diaphragm is the eleme t whi h ca s s th ai t ib at a d i b ted by th m t h n e t c pl the r lo d (rad t n imped n e) t the moto

The adiat n tr ll g eleme ts r st u t r gid n n b t g n mally n n b rbi g t u t r whi h trol the d rg nce of the ou d w e fr m ne or b th de f the di phr gm d pre nt o c tr l nt ract on betw en the fr t nd ba k d at n Th p c p l fun t n i to c a the o d pre e n the li ten g eg both by i cr a i g th en gy co er *effic n y d by d r ct ng the m tt d wa e* the d ed d t V brat n of the d phragm pr d c light lt r t n i c e se a d decrea e th i p r b and bel w tm phe c pre re In e occ r n n d s d c e oc th th At l w f eq n s the f nt p w c n e h the b ck f th di ph gm (d th b k p ess wa e c r a h the fr t f th d aphr m) b f e the d aph agm h m d pp ably He Im t c mpl te p u e eu t al zat o d t u t e t f r nce, oc s un l s igid s f baffl nte p ed n x t n i n f th di ph agm upp t Th term baffle *lly ppli d t el t ly flat tr tur* f b ta t l a a In dd t n baffles, th r m



Fg 2 Average adiation resistance reactance and mass per square centimeter of a flat r gid p ston vi b ating n an nfin te rigid nonabsorb ng baffle Piston rad ates into a sol d angle $\Omega = 2\pi$ steradians (hemi sphere) λ = length of radiated wave cm (F om K Henn y ed Rad o Eng neer g Ha db k 5th ed McGraw H ll 1959)

mon radiation controlling tructures are conven tional cabinets (open back boxes) total enclo sures (closed boxes) vented or reflex enclosures (boxes closed except for one or more openings through which the rear radiation is modified and combined with the front radiation to augment the output over a narrow low frequency range) and horns Speakers are al o frequently clas ified as horn and hornless (direct radiator) type A direct radiator peaker is one in which the diaphragm radiates directly into the listening region rather than through a horn It nece sarily employs ome other type of radiation controlling structure such as those listed above

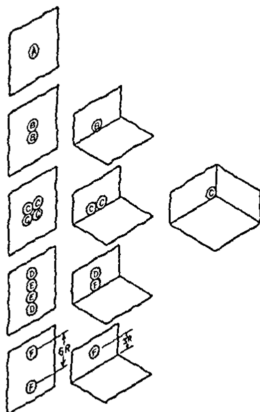
Radiation impedance The added impedance to motion of a diaphragm or ound radiating surface arising from its contact with air is called the radia tion impedance Radiation re istance is the com ponent arising from energy radiation and radia tion reactance is the reactive component A major problem to the speaker designer and one of im portance to the u er is that of obtaining efficient energy transfer or coupling from a relatively high motor and diaphragm mechanical impedance to a low air radiation impedance

The average radiation impedance per unit area of a flat pi ton is hown in Fig 2 When the length of the radiated wave λ exceeds the perimeter of the diaphragm (when $\lambda > 2\pi R$ at low frequencies) the radiation reactance is mass reactance and pro- portional to frequency and the radiation resistance per unit area is proportional to the frequency squared and to the area The acoustic power P radiated by a piston is

$$P = r v^2 \times 10^{-7} \text{ watt} \quad (3)$$

where r is the total radiation re istance (obtained by multiplying the per unit area value from Fig 2 by the area) and v the rms piston velocity cm/sec

If two or more identical speakers are mounted close together in a common plane and supplied with signal energy from the same ource the com bined diaphragms will have substantially the ame radiation impedance at low frequencies as a single diaphragm of the ombined area Differences occur as the wavelength diminishes (as frequency ri es) and approaches half the diaphragm perimeter By mounting a speaker adjacent to one or two large rigid nonab orbing surfaces such as a floor or floor wall combination the radiation resi tance may be made that of one speaker of a two or four peaker combination as shown in Fig 3 Each surface by complete wave reflection adds an image (by analogy with an optical mirror) which the diaphragm cannot distinguish from a true peaker or pair of speakers (see IMAGE ACOUSTICAL) An alternate way of con idering this effect is to note that the solid angle into which the speaker radiates is $\pi/2$ and $\pi/4$ steradians or half quarter or eighth spheres respectively A further advantage of locating a speaker in the corner is the narrower angle over which uniform high frequency re pon e is required



Fg 3 Effect of add g p to and eflect g pl n on ad ati n mped nce All p t s m rked w th the ame l tter see the same ad t on imp dance (F om K Hen ey ed Rad o Engi ng H dbook 5th d M Graw H ll 1959)

tr tched pla t d ph agm
r rf m t l d
(l ct od)

t t r l
ar r mp d

molded cyl d l ect rf
under d phr gm (pt f b)
pl ed to pro d co d l t od
Th ay so be d lect oat d

Fig. 4. S pl fied ct o al v w f a two-el c trode l ct t f p ke f th typ ed t obt pp t ly cyl d c l wa e fro t at h gh f e quencies. (F m K H ey d Rad E g r g H db ok 5th d McG w H ll 1959)

Direct radiator speakers These re the most d ly u ed p k rs Of the e bsta tially all f the general pu p se and pec l p rpo e low frequency (*woofer*) peakers a e of the m ing-coil type. Electr tat c p ake s are sometimes u d a high frequ ncy peaker (t eeter) n b ad band y t m and nf equ tly as g ner l purp se peak

Mot g-c il sp ak s W d ly ed be u e th y an co e a bro d f eq e cy ra g (5–8 ta es) these pe kers are omp ct rel bl a d low n co t. Their ailable po e r syst m effi en y is lo t p cally 0.5–4%

Th ir lati ly un form effic en y p t 1000 cps r m is att ed by pla ing the fu d mental mechanical re onant frequen y near the lowest frequen y of int rest This s th f equ ncy at wh h th d ph gm and air mas a e es nated by the d phr gm s p n ion a d a tiffn s if pr ent At f eque ie that a e h ghe than thi by a f ct r f from 2 (1 octa e) to 10 r s the n rm l im pedan e i sub ta t ally th blocked impeda ce h h n a m g l peaker is la gely re t a constant olt g and o tant ternal e st n gnal sou ill g e a fa ly nifo m cu t nd hen f rc in this range Thu the d ph agm elocity s es in rsely w th f equ n y d th r di ted p e s ind pe dent f f eque cy

El t o tat c p k In the e p ake the mechanical f es re p od ed by the ct o f le trostat fi ld St ct rally they e p it r i h b e lectrode s f e t m d rs d hragm. Th m abl lectr de i comm nly thin pl t heet w th a c nd ct e fa e whi h m y be a met ll fo l or p ted film Tw fi ed lectr des, one n e h s d of the m bl lectrode, are u ed n pu h pull types when th d a h gm ampl tude m y be r l t ely la g A gl fixed lect ode is u d n i gle-e d d type (see Fig 4) The re mm ly ed s h gh f eq ncy p ak or tweet r A high d b potential, f the o d f k l olt appl ed between the fixed d m ble elect od s to n e sen itivity and r duce d tort on Th ac potent l is uperimpo ed on the dc resulting in an altern t t g force on the diaph gm Some ad antages of the electro tati peaker are (1) the diaphragm can be very l ght (2) the for e is di tribut d er the d aphragm (3) the transient and phase di tor t on m y be kept l w by proper de ign and (4) the cost may be low Some of the disad antages are (1) the permi ible diaphragm amplitude i n mally l w leading to large area d aph agms r limiting the lower cut ff frequency (2) the norm l mp dance is substantially that f a capac tor and i diffic lt t mat h pr perly e cept n lim ted freque cy ra ge and (3) becau e of the h gh potentials d electric pr blems are in ol ed *See* ELECTROSTATICS

Radiation controlling structures These structure wh ch control the di erg nce of the sound wav and the interaction between front and back radiati n are primarily f the h rn or h rnl s en clos re types.

Enclos es These are rad ati n c ntr lli g truc tures of the hornless type. E closures may be cl ss fied as t tal in which the rear rad ti n i om pletely absorbed by the clo ed rear e cl sur nd ented r r flex in which the re r rad at on is hifted in ph e mod fied in amplitude, and com bined w th the f ont radiati n to incr ase the tot l r diat on n a freque cy ba d of appr ximately an oct e j st bo e the lowest tran mitted frequ n y At still l wer freq e ies the total ad at on i sub tant ally red c d by pres ure ne tr lization or de tru ti e i terference

T t l ncl su es are used pr mar ly when the lume is smaller tha d ir ble for a refl x type. Be u the r tiff e l mits the m nimum d a phragm–moto system tiffn s the mass mu t be r i ed to reduce the r nant f eque y In the e fle type h gh r ffi en y bta n d n the lowe t octa e by us ng l rge c b et with les a r t ff ness nd mak ng u e f the eflex o r ar ac t c n tw rk ph h ft a d rad at n A mpl fied ket h of a efl x enclo ur i hown i F g 5 The bi et a r st ff ss o pl s the diaphragm to th i m s n th nt port, reg o

ncl
p k
port
bso pt
m l

F g 5 O typ f fl e l wh h p rt l g d pl d d ph gm t bt m m m d f m th p rt d t Ph h ft f b ks d r d i n bt d by h f l l m d p rt m s. (F m K H y d R d E g g H db k 5th d M G w H ll 1959)

Horns Structurally a horn is a rigid nonabsorbing tapered duct or passage It may be straight bent or folded with concentric sound passages The small end to which the horn unit (speaker) is attached is called the throat and the large radiating end is called the mouth

Functionally it is (1) a tapered acoustical transmission line used to match the relatively high impedance looking back into the diaphragm to the relatively low radiation impedance seen at the mouth and (2) a device which by virtue of its mouth size and shape controls the directional properties

V Salmon has discovered a family of horns with interesting properties to which many common horns belong In these Salmon or hyperbolic exponential horns the cross sectional area A is related to the axial distance by

$$A = A_t\left[\cosh\left(\frac{x}{x_0}\right) + T\sinh\left(\frac{x}{x_0}\right)\right]^2 \qquad (4)$$

where A_t is the throat area x_0 is a constant fixing the axial scale of length T is a constant determining a member of the general family and the cosh and sinh are the hyperbolic exponential cosine and sine functions respectively The longitudinal sections of these horns for various values of T are shown in Fig 6 for straight axis circular horn

The performance of a horn depends principally on the throat impedance and its dependence on frequency Although waves reflected from the mouth introduce variations with frequency into the throat impedance it has been found that the average impedance is close to that of a horn with no reflected wave The throat impedance in mechanical ohms of catenoidal horns with rigid nonabsorbent walls and negligible reflected waves is given by

$$\begin{aligned} Z_t &= R_t + jx_t \\ &= A_t\rho c\,\frac{[1 - (f_c/f)^2]^{1/2} - j(Tf_c/f)}{1 - (1 - T^2)(f_c/f)^2} \end{aligned} \qquad (5)$$

where ρ c and T have been defined previously f is the frequency and f_c is the cutoff frequency given by $f_c = c/2x_0$ Thus the reference axial length x_0

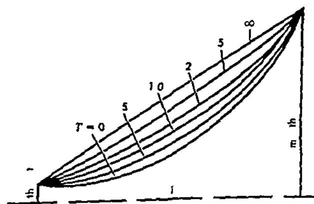


Fig 6 Longitudinal section of straight axis circular cross-sectional horns of hyperbolic exponential catenoidal family (From K Henney ed Radio Engineering Handbook 5th ed McGraw Hill 1959)

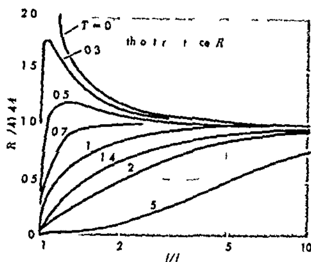


Fig 7 Frequency dependence of throat resistance for horns of various values of T Below f_c the resistance is zero The factor 41 4 is the value of ρc in cgs units at room temperature (From K Henney ed Radio Engineering Handbook 5th ed McGraw Hill 1959)

is of fundamental importance in determining the behavior of the impedance In Fig 7 the behavior of R for various values of T is shown

Speaker systems Two or more identical speakers may be used to improve the low frequency efficiency and increase the permissible input and output powers or by proper relative orientation improve the directional properties More commonly the two or more units cover complementary frequency range The more important advantages are (1) improved frequency response because each type of unit covers a moderate range (2) higher system efficiency for the same reason (3) improved directivity characteristic because the diaphragm (or horn mouth) for the highest frequency range may be made relatively small (4) improved transient response because many of the artifices used to obtain extended frequency ranges in single units make the transient response worse particularly at high frequencies (5) reduced intermodulation because large amplitudes are confined to speakers reproducing low frequencies and (6) reduced frequency modulation

Coaxial units comprise two or less commonly three speaker units mounted on substantially the same axis in an integrated mechanical assembly Appropriate wave filters or dividing networks control the amplitude and phase of the electrical signal reaching each unit The term coaxial speaker should be reserved for a coaxial unit with its required acoustic radiation controlling structure

Speaker placement In single channel or monophonic systems speaker placement is largely controlled by the desirability of uniform response in the listening area A corner location in a room is desirable to improve the low frequency efficiency and to reduce the angle the high frequency radiation must cover In stereophonic systems multiple speakers and signal channels are used to reproduce

he patial effects p ent th o gin l ou d n me t. In the e peaker pla ement is m re ritical and th reg on for ati factory r prod c i is rel ti ely lim ted The impler con enti al tem employ two han l and two pe ker or e ker t m. These peak rs e l ted m etr ally th m prefe bly l ng the h rter lL l t p al m ll li te ing r m the speake 6-10 ft ap rt. Pr perly o ne ted identical pe k s ill gi d ti l pre re a d pha e al g the pla e of ymmetry betw en the peak r h h eides th med an ertic l plan f the room. Optim m l tener l t ons in the plane f ymm t y d ghly greate than th peak r epar ti n by a f to of 1.5–_.5 Tr er e l a t ns are l m ted by th need fo h ing the m re em te pe ke les than 5 ft farthe f m the li t t p eve t the preceden e eff t in wh h th ler ignal t k s b t nt l contr l f the ar f t arr l p ecedes the l tte by approxi at ly 5-35 mill d rr p d ng t p th le gth d ff e f 5 6–39 ft F add t l ma t al n peake placeme t s ARCHITECTURAL COU TICS. [H S K]

Bibliog phy L. L. Beran k, *Acoustics* 1954 K. H (d) *R dio E n rt g H dbook* th ed 19 9 F V H t *El ct acoust Th l aly is | T du t d lt H t l B ck g und* 19 4 H F Olson *A ust c l E g e rt g* d ed. 19 7 \ S lm *J Ac ust S c Am* l (3) 199-218 1946

Louping ill

A l d se f heep cap ble of prod g en tral ert y tem m fe t t s. It h fl m the B t h I le I fect s h bee ported alth gh rar ly m g pe s worki g w th heep

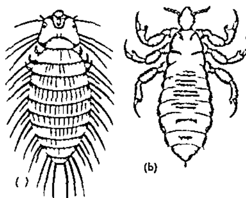
In h ep the d a e i u ally b ph w th a stemic t fl nzal ke ph f ll wed by ph l ac g l m th fi t pha e lly th ex te t f llnes

Th s m mber f th R ssian ti k b ple of the gr p B b i es Ch a t t s, d gn s, d epid m ology e m l to those f the ruse f th e mple S A IM L IRUS ARBOR VIRAL ENCEPH LITIDES [J L M]

B bli g phy T M R ers a d F L. H fall J (d) *I al d R ck tt l Inf t ns f M* 3d d 19 9

Louse

A y (r m s, i gl p t c i e t be-lo g g t the d Mall ph ga d A pl The M ll ph ga h g l e d t gu hed by h g m thpart fl tte d bod e and b d h ds. The y g es mble the d lts They lly l m t d t gle h t p l h gh (w f m ll tt k tw m e r lated h t Th d t met m call d th b d l b t g b d l e b t l p es lso t r k m mm l \ k w t p t m



( ) Ch k l se *M p g ll* l gth 0 1–0 04 (b) H m h d l *P d l h m* l gth t 0 1 (*F m E L P lm F ldb k f Nat l H st y* M G w-H ll 1949)

t be di e se t rs Se al tt k d me tic imal t bl p ultry Abo t 2 00 pe e a e k wn *S e* A OPLURA MALLOPHAGA

Th biting l fe d up f th ha p de mal cale d dried bl od n the urface of the h t They d t k blood M y cti e w ft n e s They are tra m tted f m ho t to ho t b body c nta t Ab t 40 p cies 7 f whi h mmon p a t ze po ltry Lice cau e p or h lth p ultry th gh th rr t tio d h y nfe tat on m kill y g b rds

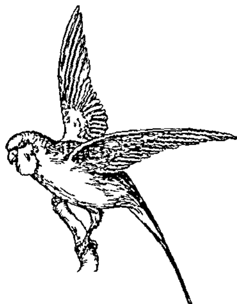
M ll phaga are e d ly t lled by l ndane pray u ed l r mb t w th DDT Th mbination i effecti e fo a wide r g of p lt yp t

The Anopl k g l re ch ra te zed b p g k ng mouthpart d n rr w u lly p t d h d Th An pl a are also mall a d d pre ed d the y g esemble the d lt Like tl Mall ph ga they a e bl g t ry p r tes d ll p nd th t life n th same h t nim l Th A pl k bl d The e ar bout 300 p ie m t f wh h m o p fic n th r h st elat ons A number f them p a t e d m t c animal l d g al sp c es cat tl d m h es d g a d h p Two mp rt t p t f m

P d lus h ma us the h ad d body l e of m n w ll k wn s the t e It ppear wh r th l g d tions f m n a e d ty a d wded It th ctor f typh S TYPHUS F ER, EPIDEMIC (LOUSE BOR F) The nim l as m d ff t form i th he d d b dy ac s b t th y ll the ame p The gg all d n ts hat h b t a w k nd ly 3 w ks eq ed t mpl te th l fe y le It w effec t ly c ntr lled d g W ld W ll by the e f DDT p wd Th ab l e f m *Phth p bis* lly fi d t the p b c a d p r nal gi s f t h t C t ry t w d ly h ld p th imal t ll el t ly mm It t kn wn t b th t f ny d e e d as ly k ll d by DDT p wd [J D B]

Lovebird

A name applied to several small parrots or para keets kept in captivity They are native either of Africa or South America The green lovebirds are American Lovebirds have short beaks and long



The loveb rd *Melop tta us u dulatu* length to 8 n (*From E L Palmer F eldbook of Natu al H sto y McGraw H ll 1949*)

narrow tails They are easily tamed and make fine gentle pets They may be taught to talk although the ability of individuals to learn words varies greatly *See* PARROT PSITTACIFORMES [J D B]

Low level counting

The measurement of very small amounts of radio activity The instruments used are special modifi cations of standard radioactivity measurement equipment designed to yield greater detection efficiencies and lower background counting rates than those necessary for ordinary applications These techniques are applied mainly to the meas urement of long lived natural radioactive isotopes and their daughter products cosmic ray produced isotopes and isotopes produced artificially during nuclear explosions

Because of the statistical error associated with the measurement of radioactivity accurate assays of samples with small amounts of radioactivity can not be made in the presence of large amounts of radiation from other sources This can be readily een from the relationship between the sample count rate A its percentage error E the back ground count rate A_b and the length of time the sample is counted t

$$E \cong \sqrt{\frac{A_b}{tA^2}} \times 100$$

For example the percentage error for an overnight measurement of a sample with an acti ity of 1 count/min in the presence of a background of 9(counts/min is 30% This error can be decreased by reducing the background or by increasing the sample count rate Doubling the sample count rate is twice as effective as halving the background Thus most low level counters are designed (1) to hold as large a sample as it is practical to obtain and to prepare (2) to record with as high an efficiency as possible the radiations from the sam ple (3) to have as low a background counting rate as possible The instruments which have been most widely used are internal gas counters solid source β counters and scintillation counters For a general discussion of various types of particle counters and a listing of related articles *see* PAR TICLE DETECTOR

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For α counting the background can be largely eliminated by selecting only the most energetic pulses produced in the counter For weak β detec tion however it is usually impossible to separate the sample pulses from those caused by β particles emitted from the materials making up the counter by γ rays entering the counter from the outside and by neutrons and mesons produced by cosmic ray activity

Gamma ray background The greater part of the γ ray background can be eliminated by placing the counter in an iron or lead shield Because of its purity mercury is sometimes used as an inner shield to remove γ radiation originating from im purities in the iron or lead Even with an 8 in iron shield and a 2 in inner mercury shield a small γ ray component remains Since these residual radiations result mainly from the reaction of cos mic rays which have penetrated the shielding their contribution to the background may change with time This is because the cosmic ray flux at a gi en point on the earth s surface varies slightly with solar acti ity and with atmo pheric pressure the former affecting the amount of magnetic shield ing required and the latter the amount of physical shielding This time ariation introduces a signifi cant uncertainty into the background counting rate in applications invol ing very small amounts of radiation such as carbon 14 dating beyond 30 000 years

Two methods for eliminating this background have been devised One is to use additional physi cal shielding to absorb the cosmic rays H DeVries found that by adding 30 in of ir n er the counter and by placing a 6-in neutron absorber such as paraffin plus b ric acid between the ir n

lectrolyt
coppe
sh ll

ce t w

t l
tico ncid nce
y t m

Fig. 1 C ss sect f p p rt l g t th i t l t d y t m Th l ge d t rep se t 0 01 d m t w d th thod f th ind d l t l t d th m ll dot th 0 001-in. d m t w wh h f m th d f th se co t Th α d β d t o g t g at th ll f th t w ll l ct t ted by γ-ray st k g th w ll rd d by th n- rnal syst m d y p d g p l th entral t l t lly ll d

and th inne me ry h eld t fold red t o in the i ble mp t can be bt d Th other m thod is t tru t a s t f a t co de e ters thin th g cou t t elf Th may be d with ries f wir as hown i Fg 1

Sin e t mode at g p res the majo ty f the ec ded γ ray a d tect d d to th f ct that el ct s a j ted f m the nt lls, rejecti n f p lses urring sim lt ne u ly n e f th t es ar the wall a d th c t t l min t m h f the γ r γ c mp t f the ba kgr d W e t t f the f ct th t part f this γ γ c mp e t rie with time th l s of ampl o ts that re lt f m t d ing th ring f e uld utwe gh th tivity gain b ght bout by the r d ct n b kgro nd

Beta part cle background Th l minated by hoos g co te m teri l with l w di t ty Steel, pper d pl t cs f t e, h e on d bly l r ad t ty tha b l minum r gl s. Th t l t de e y t m d f γ γ s effe t n r m g any d l β ad t n.

Neutrons and mesons The e p rt le a n t effect ely m ed by n lead hi ld g A p ffin h ld ll rem the n t d the inter al t d y t m w ll em the meso s. Whe i ternal y tem d, t of G g r t an be pl ed d th sample ter n h a m th t any m so t g the sampl te ll p th gh at l t e Geig te Co d t p l e r lec tr ic lly c lled A d gr m f typ l l w le el g u ter a d its a oc at d hi ld ng is hown F g 2.

Gas counters I tern l g s cou ters are used f r the det t n f c m ay prod ced carbon 14 a d tr tium The m ll q ant tie of arg n 37 and kryp- t n-85 p od ed by nuclear e plo io s can also be measu ed with su h dev es Alpha acti ty from rad n and th ron eman ti from u ani m a d thor m mineral ha b n me u ed i un hi lded gas o nte

Solid source counters Fo str n, β m tters d f r is t pes which a not be p t i to su table gaseous form low le el solid u e c nt rs a e of ten d Th c unters u ually e d wi dow pro- p rti al co te s o Geig r t be but in some as the s mple s m unt d the ins de of cyl der whi h is placed within the c unt r The latter gi a more f vo ble sample to-backgro d rat o Backg u d r d ct n is compli h d in much the am m er s f the ternal g cou ter S nce the c te are mu h m ll r m tal h eld g and a ri g f e ternal a tic cid ce t bes p oduce ffici t b ckg nd du t on A number of the isot pes s ch as str nt m 90 prod ced d ring cle r te ts ha been detected w th uch q p- m t

Scintillation counters Many low le el radio- ti ity meas eme ts are m de w th cintillat co nters The e gy of th radi t ns is erted to l ght wh ch is ecord d by a ph t multipl er tub Th meth d h p e espe ially sef l fo th d t ct on f mall q antit es f w ak β ra diat from amples liquid f rm The sample dis l ed n uitabl liquid ph ph r and pl ed i cell d g ed t fl ct all the light pro- du ed int e m r adj ent ph t m lt pl e tubes S h y tems h e fficienc es s high as 80 per ce t f r th detect n f the weak β particles f m c b n 14 d tritium.

S n e th typ f nter s mo e ensiti e t γ di t n than a d ha ge-type tube m m ph m t be pl ced phy al h ld g de s gned t b rb th γ mp t f the nat r l

h ld g

w t or par ffin sh ld g

pa f se l
mpl t

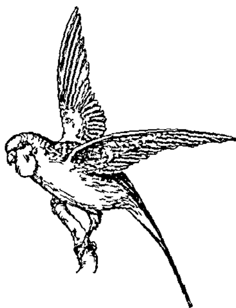
m ry h ld g

tico nc d nc
m son cou t

Fg 2 C ss sect f th sh ld g d f l g l m l l w-l l g co t

Lovebird

A name applied to several small parrots or parakeets kept in captivity They are native either of Africa or South America The green lovebirds are American Lovebirds have short beaks and long



The lovebird *Melopsittacus undulatus* length to 8 in (From E L Palmer Fieldbook of Natural History McGraw Hill 1949)

narrow tails They are easily tamed and make fine gentle pets They may be taught to talk although the ability of individuals to learn words varies greatly *See* PARROT PSITTACIFORMES [J D B]

Low level counting

The measurement of very small amounts of radioactivity The instruments used are special modifications of standard radioactivity measurement equipment designed to yield greater detection efficiencies and lower background counting rates than those necessary for ordinary applications These techniques are applied mainly to the measurement of long lived natural radioactive isotopes and their *daughter products cosmic ray produced* isotopes and isotopes produced artificially during nuclear explosions

Because of the statistical error associated with the measurement of radioactivity accurate assays of samples with small amounts of radioactivity cannot be made in the presence of large amounts of radiation from other sources This can be readily seen from the relationship between the sample count rate A its percentage error E the background count rate A_b and the length of time the sample is counted t

$$E \cong \sqrt{\frac{A_b}{tA^2}} \times 100$$

For example the percentage error for an overnight measurement of a sample with an activity of 1 count/min in the presence of a background of 90 counts/min is 30% This error can be decreased by reducing the background or by increasing the sample count rate Doubling the sample count rate is twice as effective as halving the background Thus most low level counters are designed (1) to hold as large a sample as it is practical to obtain and to prepare (2) to record with as high an efficiency as possible the radiations from the sample (3) to have as low a background counting rate as possible The instruments which have been most widely used are internal gas counters solid source β counters and scintillation counters For a general discussion of various types of particle counters and a listing of related articles *see* PARTICLE DETECTOR

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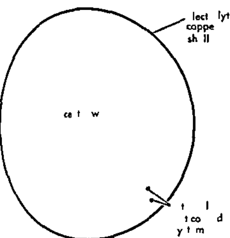


Fig. 1 C ss ct f p p rto l g t th t m l t de y t m Th l ge d ts prese t 0 01 d m t w sed th thod of th d id l t l t d th m ll d t th 0 001 n. d m t w wh h f m th d f these co t rs. Th α d β d t g t ng t th ll f th t w ll l ct j t d by γ ay tr k g th w ll d d by th n- ternal y t m d y p d g p l n th ce t l t l ct n lly lled

and the m e me cury hield a tenf ld red ctio m the ariabl omp n t can be bta ed The other method s t n tru t set of ti o den e c unte s w th the ga co te tself Thi m y be d ne with a e e of w es s h wn Fg 1

S e t mode ate g s pr s ure th maj ty f the ec d d γ a) a e detect d d e to the fact that le tr ns e ejected fr m the nter alls, reject l p l occ rr g im lt n ly ne f the re n ar th w ll nd n the ter e l m nate m ch f th γ y comp nt f th ba kground. W r t n t f the f t th t p t of th γ ay c mp ne t r es w th tim the l f ampl unts that lts f m nt d g the n g of ures ld tw gh the se t ty g n b ght bo t by the d ct n b ckg o d

Beta particle background Th s lim ted by choo g counte mat l w th low ad o t ty Steel, copper and pl t s f n t e ha e der U y l w d t ty th n b al m um gl s. Th t rn l nt in den sy t m ed f γ ay ffect n em i g ny e d l β ad t n.

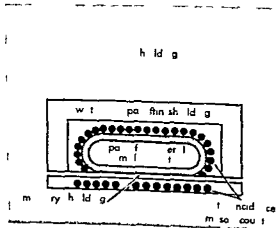
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Gas counters Internal gas o nt rs e used f r the dete ti f c m c ray pr d ced c rbon 14 and tr t um The m ll q antities of g n 37 and kryp- t n-85 produ ed by nuclear e pl ns can also be m s ed with h de ice Alpha acti ity from r d d thoron ema tions fr m anium a d thori m mi eral ha e b e meas red in un hielded g s counter

Solid source counters For t g β emitte nd f r i otopes wh h ca t be put i t a uitable ga eo s f rm l w l el l d s ce co t rs are f ten u ed The cou te s are usually e d w dow p o- p tion l c nter r Ge ger t be b t n some the ample is mou t d on the nsid f a cyl i der wh h is pla d with the cou ter The l tte gi es a m re favor ble sample to-backg ou d ratio Ba kg und redu t on i compl hed much the me m ner as f the i t nal g count S nce th c unt r e much m ller metal hield g a d a ing f exter l antic de e tubes produce a fficient b kgro d red t on A numbe f th sotope uch s str nt um 90 produc d during n lear t ts ha been d tected with such eq ip- ment

Scintillation counters M ny low l el dio- ti ity mea em t ar mad w th c nt ll ti n c nters The e gy of the radiat s c erted i t light which s re d d by ph tom lt plie t be This meth d ha pro e pec ally useful f r the d t tio f mall q ant t es f we k β r d tion f m mpl i l quid f rm The sample d ssol ed n it ble l q d ph ph and pla d in ll d gn d t efle t all the light pro- d ed i t n o m e dja nt ph tom ltiplie t be S h y tem ha ffic en s as h gh as 80 p ce t fo the d tecti n of the we k β p rticles f m b 14 a d trit m

S e th type f o nt r m re en ti e t y ad t tha d ch ge-typ t be m r em pha m t be plac d n phy l sh eld g d g ed t ab o b th γ mp n t f the atural



Fg 2 C o ct f th sh ld g d f l g l m lt l w-l l g t

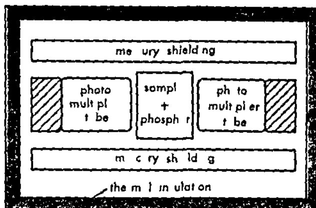


Fig 3 Idealized diagram of a low level l quid scin tillation count ng system The two photomult pl er tubes are connected so that only pulses occu r ng s multa neously n both tubes are recorded The mal back ground s further reduced by cool ng the whole appa ratus n a ref gerat on un t

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Low temperature physics

A study of the properties of gross matter at such low temperature that the quantum character of the substance becomes ob ervable Mo t famous among the effects attributed to the quantum mechanical nature of macroscopic matter are (1) uperconduc tivity (2) superfluid liquid helium (3) magnetic cooling and (4) nuclear orientation The topic of cryogenics includes the method of producing low temperatures In addition to the considerable tech nology involved in refrigeration there is a very im portant section of low temperature physics con cerned with temperature measurement and related instrumentation

Production of low temperature Low temper a tures such as those of liquid hydrogen (normal boiling point 20 4 K) and liquid helium (normal boiling point 4 2 K) are produced from the gas phase by the use of three mechanical devices (1) the gas compressor or pump (2) heat ex changers at several places along the path of flow of the ga and (3) devices for expanding the gas such as a pi ton expander and a throttle valve The e are shown schematically in Fig 1 and the flow of helium gas may be traced from the intake of the compres or pa t the water cooled heat ex changer and into the liquefier A basic concept to grasp in under tanding why the temperature drops when the gas is allowed to expand again t the pis ton is that the process has occurred at con tant en tropy Entropy S is a thermodynamic property of the system of gaseous molecule and it is u eful to think of its phy ical meaning as being that of the degree of di order of the system The entropy versus temperature plot in Fig 2 show for the gas system a eries of con tant pre sure curves The thermodynamic proce s at the compres or (with water cooling to keep the temperature con stant) is shown as the path from point α to the point β The entropy decrease $\Delta S = \Delta Q/T$ where ΔQ is the heat removed at temperature T during this reversible proce s that is a sumed to be ideal The diagram also shows an expan ion of the gas against the piston as the path from point β to the point γ This is done at con tant entropy o that one may think of the pres ure and temperature var iables as having shifted suitably to pre erve the degree of di order Energy was removed from the

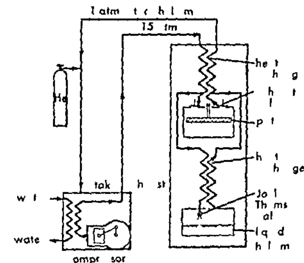


Fig 1 Eq pment for p od c ng l qu d hel um

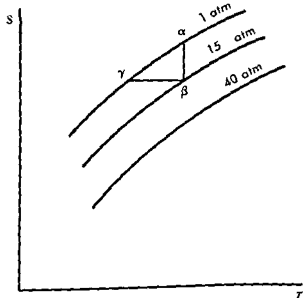


Fig 2 E tr py temp tu e pl t for hel um gas

S

b

0 05 1 0

T K

Fig. 3. E t py t mp t e d g m f p t m chro l m.

ga-o y tem by the rk t did n the piston Fgur 1 ho s till nother e pans n at the throt tle al Jo le-Th mson l e t wh ch a fu th t mperat e d p a d some l q efa t n may occu The thr ttl l e p n n t nstant nth lpy and is some hat m re subtle To s m up b iefly th modynam c ari bles m y be man pulated in ar ght rwa d manner t p du a c ld temper ture, for ampl by l qu d helium By gorous p mp g the l q id hel um the apor p e sur ay be gre tly redu ed and the t mpe atu e of the l q d bec mes f the rd r 1 K.

T p oduc temp rature b low 1 K, it s n ces sary to u a sy tem wh h nt s d s rde (e tr py) and t pe te uch a way a t br ng bo t rde a d l w th e tr py S ch a ys tem is th set f electro s with n a pa amagnet salt hose magnet c d p le mom nt may be ori ted po e ful m gnet c fi ld The e tropy et tempe at e diagram (F g 3) r pre e t a pa magnet c alt su h p ta ium chrome alum. The p oce i carr d t n two step rep e ent d by the p th t b and th n b to c In the first stage, a l rge m g t fi ld i sothe mally ap lied t th salt, nd the heat f m gnet zat n carr ed ff to the urr und ng a liqu d h l m bath t abo t 1 K The the h t ta t f the lt th the bath i r mo ed nd th st p b to the d m gn t zat n au ed by turn g off the ex t rnal magn t fi ld an ad abat p e hich the ent opy f the s lt r m s tant Dur g th l t stage the m gn t c e rgy d n ty $BH/2$ j ul /m c nta ed w th n the lt h s moved out a d d ip ted as eddy curre t heat g n th external m gnet The temp r tu e ha dropped t some 0 04 K a d the b thermody nam c r aso g s m la t the e p n g cool g f a g n F g 2 p th β t y Th de cr ted by th po ful extern l field t 1 K maint i ed by ry e k m gn t c fi ld w thi th salt beca se of the ery ub tant al dr p n t mper ature. P th b t s a c t nt nt opy p oce n

wh ch the deg e of d order remains c nstant am g the mag tic d p les The lattice vib ations of the salt are al eady n their zer point energy tate a d there mply s not eno gh entropy left to the lattic sy tem to lter the order f the elec tron d pole ystem The latt ce sy tem cannot go to debt w th a negati e entr py beca e uch a thi g is ab u d T sum up by u ng stat tical me han cs the entr py s e p e sed by means of the part ti n function and the Helmholt p tent l A as follow

$$S = -\left(\frac{\partial A}{\partial T}\right)_B \tag{1}$$

wher

$$A = -kT \ln \sum e^{-E/kT} \tag{2}$$

The e e gy lev ls E in the mag et c field B re nteger mult ple of the qua t ty βB where β is the electr n dipole moment I the ab e equation k is the B ltzm nn on tant It can be shown that the factor in the exponential $E/kT = \beta B/kT$ m st r ma n n t nt f the ent opy is to remain on tant If the l rge val e of B dr ps to the m ll i ternal dip le d pole m gn tic field w thin the alt tself b cau e f the dem gnetizati n p oces then the temperature T must become sm ll n or der t k ep th b e fa tor in the exp ne tial a nstant Th d e not demand th t the dipoles be al gned as in fe omagnet m beca e they can bec me antip allel lig ed a in antiferrom gnet m and st ll m inta n the const nt ntropy re quir me t A di n f th el ctr n sp n y tem a d magnetic c ling nat rally le d to the matter of n cl ar orient ti n nd f rther red ct n t mperature *S e* CRYOGENICS

Low temperature phenomena Consider a ol d pec men f m tt r (for e ampl a cry tal of LiF be ause the Li nucleus ha a m g et c moment) h i g c lle t on f nucle with magnetic mo ment μ wh h s taken s pa allel to th p n a gul m m nt m ch a te i d by I A cons der ble pol izat n will occ nly f the en rgy μB s l ge comp d t th energy kT becau e the e quantitie ppe r as they d d i Eq (2) fac tor f an p nti l The r quirement is mo t demandi g of e e the be t q ipp d l w t mp r tu l b at ry Magneti fields f 10 weber /m mu t b mb ed with t mpe at es f 0 01 K b fo e ign fic nt p la izat n of the n clei will b obtai ed An alternat e pp oach to n l ar pola zation i to btai larger mag eti field t th nucleus by u ng th ntri s c magnet c fi ld f th tom elect o s (f the rde 100 webe /m at u h lo r ng) The i teract n of these fields w th μ gi e r se t hype fi stru t e n pt cal spectra Th t 0 01 K mall ext rn l field of nly 0 01 w be /m n or ent the le tr n p y tem n arly to sat at n l e, d th field a t o th n clei by the spi y t m o larg that ig fica t n l r polar zat n appe r An ex m pl f p i magnet alt whose cl ar m ment may be p la ed thi w y e c rta cobalt(II) salts. *S e* MAGNETOCHEMISTRY

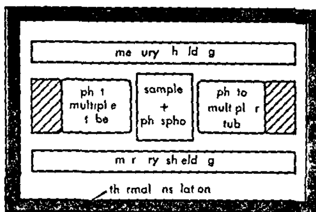


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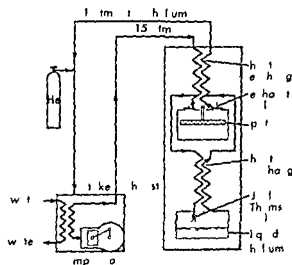


Fig 1 Equ pme t for p du i g liquid hel um

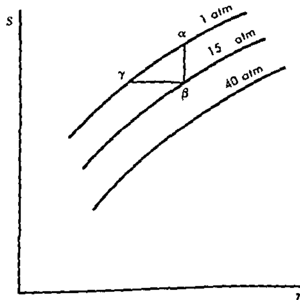


Fig 2 Entropy t mpe atu pl t f r hel m g

gas er n l ed i a fixed and k own vol me in thermal q ilibri m ith th t bject wh se t mper *ture is to be determ d* meas rement of the gas pressure ould b ffic ent for pec fi at on of the temperat e, pr ded the al e of the onstant in the equat o r lating P J nd T were known The al e f thi c n ta t is a e e arbitr ry be se the mber a s gn d t me ely fi es the i e f th d gree. Use of a si gle lu f th qu n tity a ob o s d s de t m howe e and to s- e th th been d c d d by i ternatio al agreement to ss gn t the tr ple po nt of w ter the absol te tempe atu 273 16 K A mea urement of the gas therm m t r p e re at thi relat ely as- ily rep od ed fi ed po nt f t mpe tu e then de fines the t t f r ea h gas therm m ter The f ll ing *fundam ntal diffi ulty r ma ns Altho gh* certain g ses a e mo e n arly pe fe t than others, an d l gas as ch doe not t F p c tical *me urem ts, t i the efo e n ce ary to* mod fy the mple p edu o tl ed ab e t correct f the deal hara ter f r l gase In ddit m y *the prec tio s m t b taken to* en e l able result To the ext t th t the m as ur ment h e been a ef lly mad a d p pe ly rrected al d absolute t mpe tu e a e obtained hich an be a igned l w temp ratu e eference states or th ppr pri te p mete al es of ta d ard seco d ry thermomet Bel w 1 K h we er g th rm meter b me ele s bec e the m x m m p e e at wh h gas th mom te n b per ted m t i d t min mize nid lity correcti s, l ys h pp e i bly l th n th a po pr e f the gas b g sed d at 1 K th po p es re f all g ses ther is l eady or p dly bec m g neglig bl

Adiabatic demagnetization below 1 K S nce the m eme t of t mpe t e bel w 1 K i tr bly l t d to th p d t on f th se low t pe tur s, th e t ubjects w ll be j tly d ussed. The e tial d t n f r the p du t f l temp at es is l rg e tropy dent in th t m t be cooled An th rmal d tion of the y tem entropy by an ppropr te parameter change *follow d by an i entr pi re rsal of* the ame paramet r hange to its o ig nal lue always results in a lower ng of th temperatur *At temperature f 1 K and below th e tr py* cha g s ccompanying any parameter change as o at d with g s uch as the p e re bec me *negl g ble and n f rther temp rature reduction i* p s ble To c nt nue down the tempe at e cale a d ffe ent phys cal sy tem equ red pos e ng *at the e t mpe at re large amo nts of entr py* S ce the nt py of all y t ms de re es w th t mperatur h w er the e a e f w u h s tems *a lable In 1933 W F G auque nd P Debye in* depende tly s gge ted that p ramag etic lts m ght tisfy the ab e equ reme t on tl e pre *mise that the random or entati n of the mag etic* m me ts f the paramagnet c atoms in th cry tal w uld c nt bute e en at t mperature of the rde *of 1 K an appre able mo nt to the e tropy f* the system If h a y tem is m g eti ed thermally t 1 K the elem ntary magnets will be *al gn d p rallel t th fi ld d rect on and the ys-* t m ent py co re po dingly d crea ed If th system then th rm lly ol ted nd dem g tized it *will co l i nt pically to that temp at e wh h* w uld it lf h e been ufficient in ero field t ha reduced the entropy by the me mo t s did th th rm l m gn tiz t on Th is the te hnique of l w temp atu e p d tion by ad ab t c demagnetizat o *S e* CRYOGENICS

In rd r to me re the t mpe at s p od ced by th p o ed e a new k nd f th rm m ter is r qu d Aga f tu tely the bsol te temp ra t re f a d l pa m gneti alt relat d imply t a the ily me rable q a tity its u cept b l ty d j t in the c e of g thermometry thi pa meter may be u ed to e t bli h a p o i on l tempe at re ale for u bel w 1 K This *lat hip $T = co\ t/\chi$ wher χ i* the m gneti ept b l ty of the s lt a d the tant is d te m d t s m k wn high t mp ature estab li h d by g *th rm metry is k wn as the C ri*

(a) [figure: curve S versus T]

(b) [figure: curve Q versus T*]

(c) [figure: curve Q versus S]

Determina io f th h m dy m t mp t below 1 K. ( ) Mea m t f S f ct f T (b) M m t f Q f t f T ( ) Sl p f Q-S rv g T

Nuclear orientation becomes particularly interesting if the oriented nuclei are radioactive. Anisotropy of the intensity of α, β and γ radiation from oriented nuclei has been observed experimentally. These experiments have led to important conclusions in the field of theoretical physics of nuclear interactions. *See* PARITY (QUANTUM MECHANICS).

The properties of matter at low temperatures can be most surprising. There are a large number of metals which become superconductors at low temperatures such that the electric field **E** within the metal is zero. The magnetic field described by the induction vector **B** is also zero within the metal superconductor. Many of these same metals exhibit at low temperatures (and in the normal state) an unusual diamagnetism with a peculiar periodiclike dependence on the applied magnetic field. The effect was first noted by W. De Haas and P. van Alphen and has been extensively studied by D. Shoenberg. Magnetic nuclear resonance studies on a number of systems have been useful in understanding the properties of matter at low temperature. For example, solid hydrogen is normally composed of 75% ortho molecules and 25% para molecules. The ortho molecules have the magnetic spin moments of the two protons aligned parallel, and this

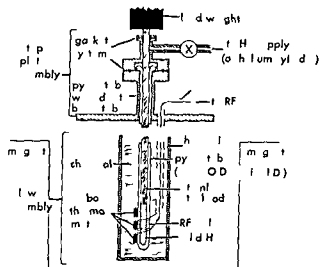


Fig. 4. Apparatus for liquid hydrogen studies.

results in allowed rotational quantum numbers of $J = 1, 3, 5$, and so on. Even in the solid state and even at 1 K, the ortho molecules must rotate. By magnetic nuclear resonance studies and by calorimetric studies the detailed way in which the molecule occupies the zero point energy of rotation has been studied. Figure 4 illustrates the apparatus for these studies made on solid hydrogen under pressure. *See* ABSOLUTE ZERO; CRYOGENIC ENGINEERING; ENTROPY; HELIUM; LIQUEFACTION OF GASES; LOW-TEMPERATURE THERMOMETRY; REFRIGERATION; STATISTICAL MECHANICS; SUPERCONDUCTIVITY; SUPERFLUIDITY. [C.F.S.]

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Low temperature thermometry

The very low temperatures produced by various cryogenic techniques are measured, like any others, by thermometers. Because conventional thermometers lose their sensitivity as the temperature is reduced, those used in this temperature region tend to be somewhat unfamiliar. These low temperature thermometers nevertheless meet the two main criteria required of all thermometers: reproducibility and a monotonic variation with temperature (preferably according to some simple law) of the thermometric property being measured. Additional conditions, such as high sensitivity and independence of the thermometer readings from magnetic field, may also be imposed for special applications. Factors such as these, as well as the degree to which the instrument must satisfy the two basic criteria mentioned above, determine the selection of the thermometer.

For accurate work, low temperature thermometers must be calibrated before each use either at a number of well known fixed and reproducible temperature points or against a suitable standard thermometer. Accurate and relatively simple standard secondary thermometers which have themselves been calibrated against a primary standard are readily available. The primary standards serve, as its name implies, chiefly to establish secondary thermometer temperature scales, improve existing ones, and accurately determine useful fixed points of temperature, for example, the triple point of hydrogen.

Low temperature thermometry resolves itself, therefore, into the basic problem of assigning numbers on the absolute temperature scale to achievable and reproducible low temperature states and the choice and the calibration of suitable instruments for the practical measurement of low temperatures.

Temperatures on the absolute scale are defined in terms of the second law of thermodynamics by the equation $T = dQ/dS$. The absolute temperature of any system is therefore given by the limiting value of the reversible heat absorbed by the system per unit change of its entropy. To determine a temperature on the basis of the above definition would be a formidable task, however. Fortunately, it can be shown that valid absolute or thermodynamic temperatures may also be obtained from measurements with a gas thermometer. Although a laborious technique, gas thermometry is ordinarily much simpler than a temperature determination based upon reversible heat and entropy measurements. *See* ENTROPY.

Gas thermometry above 1 K. Gas thermometry is based upon the concept of an ideal gas for which it may be shown that the pressure times the volume equals a constant times the temperature, or $PV = RT$. Hence, if a definite amount of such a

ow-temperature thermom t rs (Cont)

Temperature-mea uring instrum nt	Appl able temperatur nge K	Appr ate precisi n t l w temperat e lim t K	Rem k
Magnetic therm met rs	Fo all tempe a tures below 1 K (h e bec used fo speci l pu poses at h h r temper tures)	D pends upon t mperatu ange n l g ud h h m r g p ecı. on bout 0 001	Second y tand d diff e t p magn t salt samples may requre ı d d al al b t ons salts e unstable and mu t be carefully h n dled to en ure con ta y of l mic l ompo- tion useful ne rth less f 01 to 1 K using a cal br t n d te m ned e the theo et cally o e per m tally below 0 1 K the sus- ceptibility serves as a th rmom tric pa ameter
El tronic paramagnetic material h hro- mium m thylamine l m	10 to 1		
\ lea paramagn tic materials uch rop- per	10^{-4} to 10		

h A the case of a g thermometer no id l paramagn t c ex ts ny mo e than do a d l gas, a d th el e t bt n r h bl tempe tu e mea ur m nts f m 1 to b ut 0 1 K mall c recti s f r d al ty mu t be appl ed At lower tempe t these re t ons be m les and less certain, d e ntually mplet ly r liabl T est bli h o ect b l t tempe t r s th s range, it has p o ed ne e. ary to tilize the b s thermodynamic d fin t n of temper t re gi en t the beginn ng of th arti le Th d e n the f ll g ay Start ng t n absol te t mpe atur accu t ly k n by g s therm metry f r e m pl T th sc ptib l ty of a par m g et c alt s ed n e fi ld nd f m th mea ur me t m Cure l w co t nt s d te m n d Th n mai l g th sy t m t thi t mper tur l t th m g n c fi ld be bt a ly ı r a d to s m al e for ample H The e t py f th lt w ll d cr se by n amo t c rately alculable (t these t mp r t) by a athe mpl cated b t no eth l t t ble the r t cal formul As. m thi decre e n t py t be ΔS If th pa am g ne c salt is w th rmally l t d and lowly de- m gnetized sent p c proc s w ll b arried A d scribed abo e d th tempe atu will fall The ptib lity at thi w l w t mp r t n be m a ed t pr de pr l t m re tur $T = C/x$ N w let a m a r d am nt f h t ΔQ be dded t th solat d pe m n t ri n t t mpe at re to T a me ed by t ceptibil y If th pr es pe ted tarti g to f m T d g ng t T and so th a at both f S nd Q ith T n be bt n d T th n be l m ted f om th e l t hip l g S fun ı f Q The l p of thi cu th n y ld th e t bsolut t mpe t r at ted th h Q and S nd f om thi inf mation, th pr p r ect t th pr al t mpe t r bia ned fr m usc pt bil ty u em t n be made l the ll t t typ ı l c r e obt ned ın u h m asu em nts re pre ent d

Low temperature thermometers Low temp tu es ally de ı e f m the pre nce of liq e fied as a dem gn tized p ramagnet c lt e h f whi h c ta s b ilt n t mpe atur mea re- m nt c p bility ı th form f ap r pr re nd m gnet c thermomete e pect ely If howe r th low temp at e pr d ced by a ref gerator if use f the thermom ter m nt ned bo ı p o rıbed by s me pe ıal equ r ment, oth r type f thermomete m t be t l ed A ri ty f th e e a lable. th d ffer g p pe tie f whi h en ble n ptimum mat hi g of thermome- te t applic t o In th t ble me ample f the mor u es f l low temp ratur the m met s r l ted t gethe w th b ıef comme ts n their d a tag d l m tat o S e TEMPERATURE MEASUREMENT [E F H]

Bibli g aphy L. C J ck on *L w T mp ratu e Phys cs* 4th d rev 1955 N Kurti M gn ti m t ery low temp at and nucl ar ri ntat n *Nu t m nto* uppl 6(3) 1101 1957 H C W lfe (d) *Temperatu Its M asu ment d Cont ol S enc a d I dust y* l 1 nd 2, 1941 d 1955

Lubricant

A ga. l q d r l d u ed to pr ent c nt ct l pa t n rel ti e m ti n a d thereby r duce f ı tı and w ar In m y m ch nes cool ng by the l bri ant ı q lly ımp rta t Likewi th l br ant m y be c ll d upo to p v t ru ting d to p e t dep t n of sol ds on lo fitti g pa t

Liq id hydro arbon a th mo t omm ly u d lub a ts b u th y r exp s e a d ly ppl ed d they e good coolant In m t petr l m f a t n r appl cable but f pec al dit o s u h as tr me f temperat re, l t y thet l q ds may be ed At ery h gh

Low temperature thermometers

Temperature-measuring instrument	Applicable temperature range, K	Approximate precision at low temperature limit, K	Remarks
Thermocouples			Simple construction, low cost, wide range, small size, ease of installation, rapid response, no heat introduction at point of measurement; careful selection of wires necessary to avoid spurious thermal electromotive force because of inhomogeneities in lead-in wires; rapid loss of sensitivity occurs with decreasing temperature; calibrations stable except at lowest temperatures
Copper-constantan	14–350	0.1	Precision at 20 K approximately 0.0[illegible]; at 90 K, 0.01; low temperature calibration may change by 0.5 between coolings
2.1% Cobalt in gold copper	4–70	0.1	Sensitivity at 20 K about 2½ times that of copper-constantan; reproducibility of thermoelectric force between different melts about 7%; calibration valid so long as thermocouple not heated above ambient temperature
Resistance thermometers			Normally conducting metals, partial superconductors, and semiconductors have been used; all introduce heat at point of measurement
Platinum	4–1100	0.01	Basis of International Temperature Scale to 90 K; from 90 to 4 K can be accurately calibrated; calibration stable with respect to thermal cycling if Pt is extremely pure and if wires supported in strain-free configuration; at [illegible]0 K and above, sensitivity is of order of 10^{-4} degrees; Pt resistance thermometers rapidly lose sensitivity below this temperature
Leaded phosphor bronze	0.03–7	0.001	Sensitivity has been extended to 10^{-4} degrees; measured resistance dependent upon measuring current and upon magnetic field; magnetic field dependence can be reduced by addition of bismuth; difficult to reproduce same temperature coefficient of resistivity in successive wire samples
Carbon	0.0–20	0.001	Highly sensitive, capable of measuring temperature changes of the order of 10[illegible] degrees; resistance dependent upon measuring current but essentially independent of magnetic field
Vapor pressure thermometers	Triple point to critical point of all liquefied gases	Approx. 0.001	Secondary standard; sensitive; slow reading; following conditions must be fulfilled to ensure reliable results: uniform liquid temperature, uniform and known liquid composition (for example, ortho-para composition in liquid hydrogen), accurate pressure measurement; simple vapor pressure thermometers can be constructed which are rugged, reliable, and sensitive
Gas thermometers: Helium	1–800	0.001	Primary standard; requires extreme care in order to obtain accurate results; any gas whose behavior is almost ideal may be used in gas thermometer; at low temperatures this requirement restricts possible gases to hydrogen and helium, the latter being only one suitable for use at lowest temperatures; crude gas thermometers have been constructed using rough, sturdy pressure indicators to provide reliable low temperature indicators for engineering uses (gas liquefiers)

20 000
5000
1000
300
100
50
20
10
6 0
4 0
2 0
0 100 210
t mpe t e F

10464
2616 cs } 20W
1308 } 10W

sc ty rp 1h gh
d x SAE 30
typical 10W/30
m l g d

16 83 cs } SAE 40
13 0 cs } SAE 30
9 65 cs } SAE 20
5 75 cs } SAE 10
4 19 cs

g. I Visc ty t mper t l t h ps fo m lt
od ls.

I uc sity dex impr ers The fall n v ity
th incr a e n temperat re f o l f a gi en
rade, r i co ty level can be made les t ep
y th ken g *lighter oils* w th polymeric ub-
tan es ch as polyb t nes and cop lyme s f
polym tha ry1 tes The polyme may n r a n
of b l ty s the temperature cre es and o r
,o dingly the molec les unco l d *th cken* th
base o l more t high than at low tempe atu e nd
thus u teract, to some extent the natural de-
cre e n i o ty the base oil w ld u de g

P ur po nt depr ss nts The dewaxi g pro re-
oves th h gher *melting* hydrocarb n but me
c mpo e ts ull emain which may solidify and
g l the o l, nd thus ed ce its fluid ty at l w t m
per tures Sm ll amou ts of hemical u h as me
tallic *soaps, ondensation* p duct f *hlorinat d*
ax and alkyl naphthalen s or phenols, polymeth
acrylates, and a host of othe s increas flu d ty
at l t mper tures The mech ni m f their action
still unc rt in, but it probably n *ol es* ad-orp
ti n of additi e molecules on th surface f the
gr wing ax cry tals The dsorbed lay r th r
red es i tercrystal forces or m difie ry tal
gr th.

Antioxidants Lubricants are e *po ed* t x da
ti n by atm pheric oxygen in practically all of
their appl tions Thi results in format of
da a d ludges whi h int rfere with the primary
f nction of the l *bric nt. S b t ntial ncrea s n
servi e l fe* can be obta ned by u ng small am nts
(01 10⁻⁰) of anti da ts Fo l ght m e
highly refined o ls s ch as team turb ne o ls
hindered ph ols *such s d butyl p re ol* e ery
ecti e. In h avy lubr cants such as e gi ils,
amines (phenyl α-naphthylam ne) met l ph ates
(x b-earth salts of phe ol d ulfides) nd zin
salts of th ph *ph tes* and carbamate a e i w de
d use.

A s nd f t r d i g ddu es If l d
ng f es a be compl tely epa ated by l
f m, Inct nd a *will be t a min m m Ther*
m y) i ms, h e er in whi h th ombi a
tion (mpo nt geom try d pe at g nd
two i *ch th t a o t* o s l film a t be

n i tai ed but if no ep arating film of any k nd were inte p ed complete se zure would result If th pre ure and t mperatu es between u h con tacting rfaces are moderate the provision of a boundary lubricating film will ffice whereas if as n some gears onditions of both temper ture and pres ure are e re some f rm of extreme p essure (EP) l b cation may be ece ary

The form n wh ch wear m n fests itself in ma chine comp n t aries widely w th the condition from the t trophic weld ng t gether of gear *to th urfa es to the l w t n us removal of* m t l fr m an eng e cyl der e n within the same mechanical system t may change *profoundly* with chan,es n *oper t g and n ironmental condi* ti ns

In ntern l c mbu ti n engines operating at low cyl nder temperatures for instance condensation of acids from the ga eo s c mbusti n products *on* the cylind nd r ng *urfa es es lts in* orro i e *wear in uch* a es the add tio of alk l ne ea th phenates to the lubricating oil to neutral e the a d ha been ery successful in reducing wear rates

Extr me pre su e additi es Certa n types of g ar pa t c l rly the hypoids used in aut moti e re xle t ansmissi n perate u der such e ere ond tion f l ad and sliding peed w th resulting h gh temperat re nd pressu e that ord ry lubri cants ann t *pro ide complet* p otection ag nst metal contact th le ds to welding, transfer of surfa e m tal and ultimate destruction of the gear Al o in rta n machining operatio s, it is nece s ry to p e ent th ch p *from weldi g to the* cutt ng tool For s ch pplications lubricants con taining ulfu and chlorine compounds are used At the temp tu es de el ped in the c tact, these ct h mically with the metal rfaces the result ing sulfide nd *chlo ide film pro ide penetration* esistant low shear stre gth films which pre ent damag t the surfa Care in formul ting the e lubric nts must howe er be exer ised to e sure th t rrosion *f metal at normal temperature* d n t occur Figur 2 shows the damag ng re-ults which may occur the absence of s ch p te t e add ti

Dispe sants In i t rnal combu tion e gi es om of the p odu ts of comb tion wh ch in lud rbona eous part cle part ally burnt fuel ulf r acids nd wat r enter the oil film on the cyl nd r wall These m ter al m y react to fo m la q ers and l dg s *which are deposited on th* w rki g p rts f the eng ne. The lubr ant is called

w gea sc g pi w g

Fg 2 Typ of g f l

temperatures or in places where renewal of liquid lubricants is impossible solid lubricants such as graphite or molybdenum disulfide may be employed

Petroleum lubricants Crude petroleum is an ex cellent source of lubricants becau e a very wide range of suitable liquids varying in molecular weight from 150 to over 1 000 and in viscosity from light machine oils to heavy gear oil can be produced by various refining proces es Studies carried out by the American Petroleum Institute and others have established that crude petroleum fractions consist of saturates (normal iso and *cycloparaffins*) monoaromatics which may contain saturated rings as well as saturated side chains substituted polyaromatics hetero compounds con taining sulfur nitrogen and oxygen and a phal tic material made up of *polycondensed aromatics* and hetero compounds Of these the wax free atu rates and monoaromatics are desired in the finished oil in order to obtain the desired viscometric prop erties and oxidation and thermal tability and so far as po sible the other types of compounds are generally removed Classically only those crudes (so called paraffinic crudes) relatively rich in the desired type of hydrocarbons were used in lubricat *ing oil manufacture By atmospheric distillation* neutrals were produced as distillates and the resid ual fractions were treated with activated clays which removed a phaltic and hetero material to produce bright stock

In modern refining vacuum distillation removes the desired hydrocarbons from the asphaltic constit uents (which may be present in amounts up to 40% of the total) and gives oils in the required viscosity and boiling range Extraction of the distilled frac tions with solvents such as liquid sulfur dioxide furfural and phenol permits the removal of the polyaromatic and hetero compounds to improve *viscosity temperature characteristics* (viscosity in dex VI) and stability of the oil Dewaxing removes the high melting paraffins

If the viscosity index of the oil is not important for a particular application the most reactive poly aromatics and hetero compounds may be removed by treatment with concentrated sulfuric acid In either case the oil is treated finally with an active clay to remove trace amounts of residual acids and re ins *(heterocyclics)*

Small amounts of heterocyclics such as substi tuted benzthiophenes quinolines and indoles may remain in the finished oil The sulfur containing compounds erve the useful purpo e of acting as natural antioxidants The nitrogen compounds may be harmful in certain applications because of their propen ity to form deposits on hot surfaces and are generally reduced to low concentrations

The table lists typical *specification data for lubri* cants in everal applications It will be noted that vi cosity is a determining factor in lubricant selec tion Machines are generally designed to operate on the lowest practicable vi cosity since the lighter fluids give lower friction and better heat transfer rates However if loads or temperatures are high

Viscosity of o ls for var ous applications

Applicati n	V scos ty cent t ke at 5 C (77 F)	Pr ma y f t n
E g ls		
SAE 10W	60–90	Lub at p st n i gs, cyl d rs, al ge be gs cool p t n p e nt d pos t n metal s f ces
SAE 0	90–180	
SAL 30	180– 80	
SAE 40	80–450	
SAE 50	450–800	
Gea o ls		I t m tal co ta t nd w a of sp g rs, hypo d g ars, wo m g a s cool gear cases
SAE 80	100–400	
SAE 90	400–1000	
SAE 140	1000– 00	
Avi t on e gin ls	0–700	Sam g n o ls
T que conv rter fl d	80–140	Lub cate tr n m t pow
Hydr ul c b ke flu d	35	Tr n m t power
Refrige to il	30– 60	L b icate compresso pump
Steam t b e o l	55–300	Lub cate r d t on g a g cool
Steam cyli d r oil	1500–3300	Lub cate in p esence f st m t h gh tempe tu es

more viscous and less volatile lubricants are re quired Change of viscosity with temperature is often of considerable practical importance and it is customary to express this in terms of vi co ity index an arbitrarily chosen scale on which an oil from a Pennsylvania crude high in saturate and monoaromatic content is assigned a value of 100 and those containing a relatively large amount of cyclohydrocarbons both paraffinic and aromatic (from naphthenic crudes) will be in the 0–50 vis cosity index range As already de cribed the re finer can produce oils of high vi cosity index from naphthenic stocks but yields may be low

Multigrade oils In order to standardize on nomenclature for oils of differing viscosity the So ciety of Automotive Engineers (SAE) has estab lished viscosity ranges for the various SAE desig nations (see table) By the use of relatively large amounts of additi es for improving viscosity index it is possible to formulate one oil which will fall within the range of more than one SAE vi cosity grade the so called multigrade oil illustrated by Fig 1 Since all viscosity index improvers also in crease visco ity it is necessary to u e a ba e oil of low iscosity to formulate such oils Since the is cosity increasing effect of the additive decrea es with increase in hear rate an artificially thick ened oil of this type behaves as a light oil in en gine parts under high shear and thereby friction is low but acts as a heavier oil in low shear region or at higher temperatures However olatility and *ability to protect* high shear parts from rubbing set limits to the use of light oils in the e formula tions

Additives for lubricating oils It is often de ir able to add various chemic ls to lul ricating oil to improve their phy ical *proj ertie r to btain some* needed impro ement in p rf rmance

k peed PTFE l d n it elf or on m tal h effi ie t f fr t in the l we t range observed fo bounda y lubricat on (ab t 0 05) The frictu n ri es t alue comm n for other plas- t ft r the liding j e d p e tic l lue d th h gh fri t n tends t per t when ret n g t l peed

It l k ly that th is the m l effect the i ci d f hi h pr m ted by the extremely l w therm l du ti ty f PTFE d it can be com bated t n derable extent by ing tl e PTFE in pp m t ix The e f su h a mat ix l o educes th ea hich w ld ccur with PTFE al e. Th t p of tr tur i ed s a elf lub t d bear m te l

Greases A l b c t ng gre e a lid r em f d l br c t mpr g a th kení g (or gel l g) g nt n l quid l bri ant. Other ingred e t imp rt g pec l p pe tie m y be i luded An importa t p p rty f a gre e its sol d nat re t ha a yi ld l Th en ble grea e t r t in itself a bearing s embly w tho t the a d f t pe e se ls, t p d it o n eal ag n t th ingres f m i t e and d t, nd t emai n rti l urf es d ff rd p otect o g t m i tur or n, espec lly dur h t d wn per od

The g ll g a t u ed n m t gr are fatt ar d soap f l th m d um cal ium a d al mi m, P ta m ba m nd le d s p ar ed oc lly The f tty d employ d a e ol f lm t c, t c, a d ther c b yl id d med f m m l fi h and eget ble o l The f soap n gr e s l m ted by pha e h nges (r melt ng p ts) that oc r in the r nge 50–200 C Becau e many applicati s r quir perati n ab e th s tempe ture grea es ha been i troduced which are th ck ed by high melting sol d such a lay lic org nic dyes rom tic am de and ea d at e In the e ca e the upper l n it of appl cat n et by the ol t lity or by the xida tio and thermal tabil ty of the ba e il To exte d the pe ting ra ge to xtreme of h gh d l w temp atu e ynth tic o ls m y be u ed as the ub- trate Sil on e ters nd flu r carb s ha e ll b en empl yed f r this p rp e As in the e f l qu d l br ant a u dd ti e uch as xida t on nh bit EP a nts and anti u t add ti s e freq ently u ed in grea es V l til ty f the b e o l i part cul rly mpo ta t in g a e be cau e t is on tantly po d a thin film n the b ar g u faces

Structure of greases The gelli g age t in m t soap-ba e g ea es s pre e t as crystalline fibers ha g l ngths f l 100 μ and d amet s 1/10–1/100 f th l ngth Th fibe th ck n the o l by form g n tw k br h heap struct e n whi h the l i held by cap ll ry f c s F a gi en concen t at n f ap the l ge the l ngth to-d ameter ti f the fibe the g eate i the p ob bil ty f network ju t n f rmat n d the ha de i the g e H w er not all ap f rm s h y tall ne fibe lum n m ap a n t bl except n The e de e that l min m oap mol ules f m etwork k t th t f med by p lyme m l cule N so p th ck ners a e pre ent a m ll isom t part le m h m lle th n l μ i l ea ize

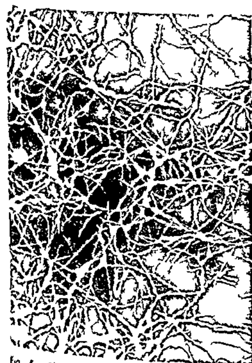




Fig. 5. Elect m g ph of g t t 0,000 ( ) So p-th k ed g grease. (b) Dye-th k d

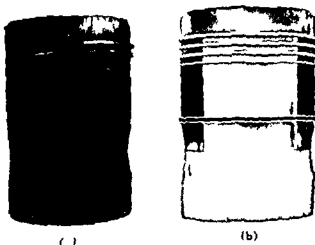
upon to keep engine parts (oil screens ring grooves) clean and this is accomplished by th use of o called detergent oils Performance is il *lustrated in Fig 3*

The most commonly u ed dispersants are alka line earth salts Of the e the most successful have been the salts of petroleum sulfonic acids phenates alicylates thiopho phates and oxidized olefin phosphorus pentasulfide reaction products The e materials owe their effectivene s partly to their urface activity which ensures that foreign parti cle are kept in suspension in the lubricating oil and partly to their alkalinity which enables them to neutralize combustion acids that would otherwise catalyze the formation of lacquers

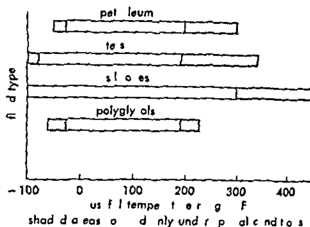
Polymeric additives have been introduced for di persancy They are copolymers of a long chain methacrylate for example lauryl methacrylate and a nitrogen containing olefin such as vinyl pyr rolidone These nonash dispersants are uperior to the metal containing additives for low tempera ture operation and can be u ed very effectively in motor oils Because they are less alkaline than me tallic additives the polymeric additives are le ef fective in diesel engines who e fuel often lead to combustion products which are much more acid than those from gasoline

Boundary lubricants Boundary conditions are encountered in many metal forming proces es in which the pressures *required to deform the metal* are too high to allow an oil film to form In uch applications fatty oils such as palm oil or lubri cants containing fatty materials are employed to *reduce the friction and wear the fatty acids react* with the metal surface to form a tenacious oap film which provide effecti e lubrication up to tem peratures approaching the melting point of the soap usually about 120 C *See* MACHINABILITY (METALS)

Synthetic oils During World War II synthetic lubricants were extensi ely employed by Germany as substitutes for mineral lubricants which were in hort supply Some of these such as the ester oils were in fact superior to mineral lubricants in some



Fg 3 The effect of d spe s ts on clea l e (a) Or d nary o l (b) Same o l cont n ng d pe sa t add t e



Fg 4 Usef l temperatu e range of synthet c o ls

applications Since the war the u e of synthetics for pecial applications where their performance ju tifies the higher co t has teadily increa ed Their main advantage is that they have a greater operating range than a mineral oil (Fig 4) E ters such as 2 ethylhexyl sebacate containing oxidation inhibitors and sometimes mild extreme pre ure additives are used as lubricants for aircraft jet en gines Silicone although ideal with regard to ther mal stability and viscosity characteristic are poor lubricants for steel on teel and this has re tricted their u e although they are invaluable in some ap*plications Another class of widely u ed synthetic* oils are the polyglycols such as polypropylene and ethylene oxides The e polymers are available in a wide molecular weight range and they vary con *siderably in solubility in water and hydrocarbons* Thus water base lubricants may be formulated which are employed when a fire hazard exi ts

Solid lubricants The most useful solid lubricants are those with a layer structure in which the molec ular platelets will readily slide over each other Graphite molybdenum disulfide talc and boron nitride possess this property

The principal difficulty encountered with the use of solid lubricants is that of maintaining an adequate lubricant layer between the sliding metal surfaces If the solid lubricant is applied as a su pension in a fluid there is a tendency for the par ticles to ettle out and they may not reach the region where they are required If they are applied as a thick pa te to overcome the tendency to ettle out it is frequently difficult to force the pa te through the narrow clearances between the liding surface A third method is to pretreat the surface *with a relatively thick film* of solid lubricant us pended in a resin and bake it n Difficulties may then ari e through progressively increasing clear ances as the film wears and of course there is no *method for its continuous renewal* Materials such as graphite and molybdenum disulfide oxidize quite rapidly in air at 400 C Unle s air can be exclud d therefore alternative solid lubricants will be r *quired at temperatures greatly in exce s of thi*

A unique type of solid lubricant i pro id d b the plastic polytetrafluoroethylene (PTFE) At

h ted by frict and by heat transfe from the hot engine parts, coll cted c led nd pump d back int the e gin I aut m b le th oil r t rns by gr ity t the rank The air m t n er the tside f the rankc is u lly ffic e t to cool the o l. It is then p mped f m the c ank case ba k to th il distributi g galle es n th gine. I high utput gi es the il i pumped f m th c ank se nto a sto ge r serv and then through an air o w t ooled heat ex hanger n the y back t the ine.

In pla h l bri t n, the l nt ri g the e gin flo s to t o ghs into hich e te s f the n necting ods dip (Fig 1) Th dipp g ction fo ces il th gh h les at the b se of the s ps t the c nnecting od bearing nd th pray pro d ced the t gh d trib tes o l t the cyl d alls f om hich t d ips and r n by gr ty int passages t ther b ing

Fig. 2 F ll p ss l b t (B k D f G l M I C p I)

A m re po iti di tr but on m thod c lled f e-feed or full p essure l b ic tion is u ed in h h tput ng s (Fig 2) In this yst m the pump f rce th o l at c n d able pres ure thr gh p ges t ea h main ank h ft b ing. The ank haft i d illed t c ey the l fr m the m b a gs to th c nn ti g rod bear ings. Som tim s the o necting rod d lled to arry the l t the wri t p ns E cept th larg t engines, the cyl nd r walls lub ated by l ak p y f m th d f th nne ting od bearings. In the f rce-fe d y tem the p mp p es ure ins res a te dy epl c m nt f the l wh h ha been h ated by f t work w th f h l l f m th e r nkca r serv i l th w y the t mper t d th ef e the w k g o ty f the l n th be g are o t ll d

Wear c e the l br c ti g l fl w t all p t f th k e, t mport nt tl t t d n t ry h r e m t r l w th t S h m te rial m y c me fr m the combu tion of th f el f om dirt n the ind t d air o fr m part f the e g itself It mmon p t e to filt r all or p rt f the o l t flows thr gh the sy tem to ed e we A large part of the cylinde w r oc rs dur g t rting and b f r the eng h warmed p Cold oil b ng quite iscou l w to h th beari g and the end le k ge pray nto the cylinde wall is greatly ed d At low engine tempe tu e there is an in ea ed tend ency f rr i e products f mb tion to con d n o the cylind w ll Ch mi al additi es are d in mode n e g n il to increase the isc ty index red rr i e action and sludge and m p il perfo m nce in riou th w y

Exce si e use f l m y b a d by w f g yl nd bo e il of improper ty l kag pa t the shaft seals o loss of vapor from the c ank b th By d n d m ntenance l mpt n can be made mall. The p incipal object on t hi h o l fl w into the comb t n sp ce m ky xh t f uling of p k plugs and bon dep s ts in the cylinders S LUBRICANT

[A R R]

Lumber manufacture

The w g of logs int mm ally usef l boards dim n lumb o t mber d the drying and planing to finished p tt rns and size Lumber p o d t in th United St t in e 1950 has g d around 38 000 000 000 board feet per y ar f whi h b t 80% is softw d and the emainder h dw d *See* WOOD (ANATOMY AND IDENTIFICA TION) XYLE I A board f t s b a d l ft quare and l thick, or t qui alent in oth dimen ns In the Unit d Stat the ftwood lumber industry s concentrat d in the West and in the S uth Hardwood lumbe is p oduced primarily in the G eat Lak states th Appal chians and in outhern wamps and ri e b ttoms whe e cypre s s also awed *See* LOGGING (FORESTRY)

Sawmill operation Log are t red t the mill in a l g pond r n dry gr und to be mo d l ter to the con ey r chain h st, r th sy tem which d li e s th m nto the mill Land st d log must b sawed p omptly to a d dete or t on from fungi and sect In the mill l g are sawed by a ir ular w a b d saw or a log g ng aw (e SAWING) The cir lar w s cir ular sheet f t l ar und the dge f which are cutti g teeth ri ly h p d f d ffe ent types f s wing Band s w e dle band of teel runni g e tw whe l d h e c tting teeth n o or both edge A log g g w c n st of st el f ame in whi h th aw ar nd du lly pla ed with the d ired d tance betw en them Ten on i appli d t the aw and th frame s th n mo d ap dly p and d wn w th a l ght f rward o ll ti g t n on the d w r tti g, t k Log fed th o gh the g g w e firmly h ld b p ur r ll t a s t aight tt g

Th ck l he d ws w th r pl bl te th e d w th m ll port bl mills b cause thi

Silica particles are round and some clay particles are plates Forces of interaction between silica clay particles and oil are easily destroyed by water so it is necessary to waterproof the primary particles by special treatments Electron micrographs of various types of greases are shown in Fig 5

Mechanical properties of greases When the applied stress exceeds the yield stress the grease flows and the viscosity falls rapidly with further increase of stress until it reaches a value only a little higher than that of the base oil This fall in viscosity is largely reversible since it is caused by the rupture of network junctions which following the release of stress can reform However continued vigorous shearing usually results in the rupture of fibers and permanent softening of the grease Here certain greases such as those derived from lithium salts of hydroxy acids are superior to other types although the manner of grease preparation exercises considerable influence

In a major grease application for example ball and roller bearings shearing between the races and rolling elements is extremely severe The reason why a good bearing grease does not soften and run out lies in the fact that only a very small fraction of the grease put in the bearing is actually subjected to shearing As soon as a freshly packed bearing is set in motion most of the grease is redistributed to places where it can remain static in the cover plate recesses and attached to the bore of the cage between the balls or rollers The small amount of grease remaining on the working surfaces of the bearing is quickly broken down to a soft oily material which lubricates these parts and because it has only a low viscosity it develops very little friction

A number of methods exist for the measurement of yield stress and viscosity at various temperatures One of the oldest of grease tests still universally used is a consistency (hardness) test in which the depth of penetration of a cone of standard weight and dimensions is determined However few of the many tests used are helpful in predicting the performance of a grease Consequently in development work recourse is made to actual performance data and to the use of rigs that simulate field conditions *See* BEARING ANTIFRICTION GEL PETROLEUM PROCESSING [R G L]

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Lubrication engine

Continuous supply of a viscous film between moving surfaces in an engine during its operation Relative motion between unlubricated surfaces of engine parts would result in excessive wear overheating and seizure with destruction of the contacting surfaces The energy loss associated with the wear and overheating would be evident in reduced engine power and efficiency The purpose of lubrication is to minimize these effects by interposing a viscous fluid called the lubricant between the parts Hydrodynamic forces are produced in the lubricant to keep the surfaces separated even though heavy loads are tending to bring them into contact The thickness of the separating film for a given part geometry depends upon the relative velocity of the two surfaces the absolute viscosity of the lubricant and the load per unit of surface area

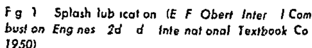


Fig 1 Splash lubrication (E F Obert *Internal Combustion Engines* 2d ed International Textbook Co 1950)

Lubricant Engines are generally lubricated with petroleum base oils containing chemical additives to improve their natural properties Refining methods and composition may be varied to suit special engine design operating conditions Perhaps the most important oil property is the absolute viscosity which is a measure of the force required to move one layer of the oil film over another With low viscosity a protecting oil film between the parts is not formed With high viscosity too much power is required to shear the oil film In addition the flow of oil through the engine is retarded

The viscosity of oil tends to decrease as its temperature is raised It is therefore difficult to maintain the proper viscosity as the engine warms up or as other operating conditions change Viscosity index is a number which indicates the resistance of an oil to changes in viscosity with temperature. The smaller the change in viscosity with temperature the higher is the viscosity index of the oil

Lubrication system The function of the lubrication system is to supply clean oil cooled to the proper viscosity to critical points in the engine where the motion of the parts produces hydrodynamic oil films to separate and support the rubbing surfaces In all but the most primitive lubrication systems the oil which has been

ar tr lled L mb r c n be dri d in kil to th desired mo ture o te t m h more pidly than t d y F r example in k lns l in green th rn g n l mbe can be dr d to l c mo tu e t nt /2 h u (Fig 3) M h ftwood lum l k l d d not ly t edu ts w ht and u e f ght b t also t gi e t bette util ty M t ha d ood lumber is nly dr d t awm lls and h pped r h Th s be u e f the diffi ulty of r p dl dry g m t ha dw od and beca e the f h rd ood l mb ch a f rn tur fa t ies p f r t dry the l mbe th m l that If they p r ha e from ar us our es will be of l rm m tu e c t nt when u ed Rough dry soft ood l mber i fi h d in pl ning mill u ally nnected th a mills to exa t b d ize or ding or t ce l ng nd flo ri p tterns Finally it graded and sold

Grading F r epar ti n nt eful cl ssifi a t l mbe gr d d c d ng to r le pre scribed by m n fa t r d ma ket g s c a t All Am r a l mber gr d g ules m t the pec fic t s of Am r can Lumbe St nda d de l p d by the U.S D p tme t f Commer The r les ry l ghtly m ng the lumbe p d i r g s b t th y m k all yard and n t u t n l ber nter hangeable i e L mber grad g rules whi h ba d n th inte ded u e of the l mber re f th e b c typ s O e s y rd lumb r that used in gen r l construct f h e l m and m l st ctures An the i stru tur l lumber f r h a y nd t i l c tructi wh e tr ngth i impo ta t The third i f ct y nd h p

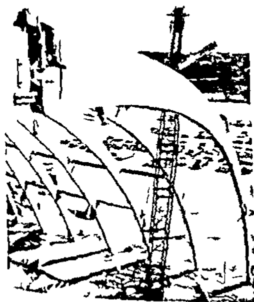


Fig. 4. Gl d lam t d the p ch h h lor Al F l 10 000- t p rt mph theore in W st P lm Be ch Flo d P d g l two f 247 ft th se w ld l g t w d h only 12 sq ed for e t t t l pp rt f th b nding (S th P ne Ass t)

Fig 5 O all iew f J Al F nt E ch h w gh o e 15 t s (U t St t e l)

lumber thus cl s i usu lly cut p befor ult mate e Yard and truct ral lumber i graded for se of the p ec a wh le bec us each i of tandard width thickne and length Grades e b s d on th umber and ext nt f knots pl ts de ay and mil r n tur l defects M ture ont nt nd di m ion pecificat on are also on d ed When l mber t be ed in tructures in wh h stre gth i mport nt the de sity of the gr n ts stra ght ne a d kn t omb nat on that wo ld impair strength r al l ated Nea ly ll h dwood l mb r nd ome ftwood gr ded on the fac t ry nd h p ba bec use such lumber i u ed by f nit e nd other fa t r es wh re t is ut up to lear (o def ct e) pie e Hen e hardwo d a d oftwo d hop l mber s gr d d from the po re f c (s rface) whe ea ya d and st ct ral lumb gr d e b ed n the b tte face B e of the mp rtan of u ng th r ughly d ed a d c rr tly g aded lumber m h f it s ffic lly g ade marked by ffici l grading ass ci ti ns and t ade marked by n ti ally k wn ma uf tu ers. L mb r f o truct n q lity i st e s ated a c d ng t grad ng ules o that rchite ts and en n r ca d ign t ct re l wo d a afely th y an th e f metals o m nry

Laminated wood F b icating wood n p nel beam d t s by gl g smaller piec s f lum be t ether called l m nat ng (s PLYWOOD) The g g c ty l larg tree f m wh ch la ge t mber b wed h t mul t d l m n t ng whi h wa nt d ced into th U ted State in th 1930 Lam n ti g l p m t pref bricat g la ge t e d ar h s t stre gth and e p ci fi ti (s ARCH T USS) In 1954 th lumb r d gl d l m n t d tructu e t t) d 125 4 0 000 boa d ft f h h e 90% w s u ed n b dges b ild g nd the tr t es D gl s- fi d th n p n r th m st w d ly u d wood fo lam at ng th W st and E t re p c t ly b th y b th h e de. bl t e gth q l tie Oak l d hefly f mar e l m ate Lam ated wood c n r ad ly be imp eg ted w th p ri t and fi ret rd t th han ing t ful (F g 4-5) S e FOREST FORESTRY WOOD FI ISHI G WO D PHYS CS WOOD RE FR ATIO [A F W]

B bl g phy N C. B w a d J S Beth l *Li ib* d d 1958



Fig 1 Log deck of a cypress sawm ll in Flor da show g log co veyor t ough on r ght ca r age w th log be ng sawed at left a d at ear the ba d s w hous ng Th awyer s out of view (Photograph by A Lescheu and S s Rope Co)

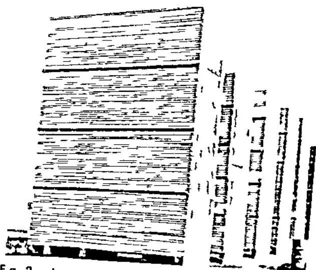
kind is most readily kept in good cutting condition However they are the most wasteful because their kerf or cutting thickness often is ¼ in which means that for every four boards 1 in thick that are cut another possible one is lo t in the form of sawdust

Logs enter a mill on a conveyor chain and are stored on a log deck They then are placed on a carriage where they are positioned and moved against the saw The carriage is powered by a cable and drum or by a large steam piston As boards are sawed off the log is repo itioned for the next cut by a setter who rides the carriage The sawyer standing by the saw operates the carriage the log turning mechanism and the device that moves logs from the deck to the carriage (Fig 1) Some newer carriages have set works that the awyer operates by remote control All of the e operations are quickly performed and there is little unproductive time with killful sawyers Logs are turned as saw ing progre ses to obtain the maximum amount of the better grades of lumber As the boards are awed they are conveyed to the edger if they are to be ripped (made narrower) or they move di rectly to the trimmer where they are cro cut to the correct length

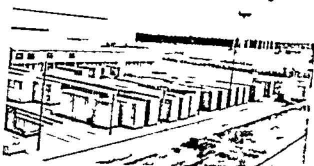
From the trimmer the boards go to the sorting table where they are separated by grade ize and species At some mills the boards are dipped in an anti eptic solution to pre ent fungus taining while drying Many of the larger mills use re aw o speed production With them thick cants (large ize dimen ion timbers) are cut on the head aw nd the e then go to a sa h gang re aw or to a band esaw that cuts them to final thickne es Wood a te if needed for fuel is hogged (mechanically hipped) and ent to the fuel house The large ood requirements of the pulp and paper indu try ave created a market for sawmill waste in the rm of chips (*see* PAPER AND PAPER PRODUCTS OOD FIBER PRODUCTS) Much wood formerly ted or u ed uneconomically is now converted into pulp chips and old Bark is not acceptable for pulping (*see* BARK) Therefore at mills that convert their wa te to pulp chips logs are de barked before being awed There are everal type of mechanical and hydraulic debarking machines

Sawmills range in ize from mall portable mill cutting 6000–8000 board ft/day to large ones with two or more headsaws and resaws cutting everal hundred thousand board ft/day At portable mills logs are skidded directly to the log deck

Lumber seasoning Lumber is not fully proce ed for use until it has been dried to a moi ture content conforming to that of the place it will be used Otherwi e it will shrink or swell and may decay Lumber is air dried in stacks in a yard where air can circulate through it (Fig 2) When air dried it contains about 18% moi ture in terms of its oven dry weight Air drying requires from 3 weeks to a year or more depending on the kind of wood it thickness and the weather For fa ter drying and to attain lower moisture contents than are pos sible by air drying dry kilns are u ed The e are chambers in which tacked lumber is placed air circulation is forced and temperature and humidity



Fg 2 A a -dry ng p ne l mber ya d n no th Lo ana (Ph tog aph by Wooda d Walke L mber C)



Fg 3 A b ttery of dry k l s t a southe p aw m ll i Te as how g l mb st ks o t cks ady fo pla g the k l (Ph tog aph by K by L mb C p)

cla ific u n based on p r istenc of the aftergl w not m aningful because it depends on the pr p-erties f the detect r ed to ob erve the l m es-nc W th appropr ate instrume ts one n detect aftergl s l ting o more th n few th andth f a mi r seco d, wh ch would b imper ptible to the hum n ye. The ch racter zatio of uch a lu minesce e a either flu e cence or ph pho es-ence therefore d pe d po whethe the bserv u is made by ye r by in trumental mean These terms a ne erthel ss c mm nly used in the sense d fined he e and are on ient fo m ny practi al purpo es Ho e er th y can b g en mo p eci e m ing Fluo e cen e may be de-fined luminescence emiss n ha g an aft r gl du ti which temp atu e-ind pe dent. Ph phoresce ce m y be defi ed a lumine ce ith afterglow du ti wh h bec me sh t r h increa g t mpe ature F r details n ar io t pes of lumi ence e BIOLUMINES-CE CE CATHODOLUMI ESCENCE CHEMILU II ES-CE CE ELECTROLUMINESCE CE FLUORESCENCE PHO PHORESCE CE PHOTOLUMINESCENCE THER MOLUMINESCE CE

Because of th r m y pract l appl cat s, mat al that g e sble luminesc ce ha e been st d ed d devel ped mo e t n ely th n those h h emit in th pectral regi ns Lumi esc e, h ev r m y on t f radiati in ny egion f th el t magnetic spectrum The p o-duction f rad tion by th bombardm t f a metal ta get by fa t lectro b *am i n ex mple f lum esc* Certa flu re ce t l mps call d bla k l ght lamps, a e coated w th a lum escent po der ch se for ts ab l ty t emit ult l t light of pp o imat ly 3600 A the th i bl l ght (s ULTRAVIOLET LAMP) A numbe f lum nes t sol ds ha e b n de el ped wh ch lumi nesce n the e r i fra ed und x tation by ibl l ght r by th de-ray b m

The b l ty *to lum* sce i t c nfined *to* any partı ular tate of m tter Lum e e i b-served in gases, l q ds, nd sol d The pas g f an electr al d sch g thro gh a gas will e t the g seou t m m lecul t *lumi* esce u d nai nd ti ns. A mple f such a g eo luminesce e s the me ry p r lamp in whi h an lectr c l d scha g e tes the me c ry ap t emit both i ble a d ultr i l t l ght (*see* MER CURY VAPOR LAMP) M ny l qu ds, uch as il sol ti f c rta n d t ff i u sol nt lumi esce ery t gl nd ultr let l ght. A large umber f sol ds, l ding m y tu al min al as ll th usa d f synth ti in r ia ic d g n c compo d l m sc nder ario types of e t t o The maj ppl cati f luminesc e l e sol d l m nesc t m t als.

Th t m g h ph r g ally ppl d t t sol d that h b ted l g ft gl ws, has b ex t ded t in l d y lum esce t sol d g rdle f t t gl w p pert Oth terms som t m sed ynonym ly th ph ph r e l m n phor g r fl h The te m lum ph r p fe able, nc t rr n tat th t aft rglow time are l ng or sh rt In nf rm ty w th urrent u ge, howe r the term ph phor will be u ed in the ucceedi g di cu sion of ol d luminesce t ma te al

Compar ti ely few pure solids lumi esce effi c ently at lea t at normal temper tures In the c teg ry f organ olids the p re aromatic hy droc bo s, such naphth lene and anthracene wh h c ns t ex lusi ely f conde ed phenyl *ring a e luminescent as re many hete ocyclic* cl d ring mp nds How er the losed phe yl r g st ucture is not in t lf a gu ntee of effi ient l m n sce ce ince ert i s b tit nts for hydr gen the t uctu particul rly halogens tend to educe luminescence efficie cy Am ng the pu i organ c s l ds that lumine effi ently at room temp tu are the tu gst t s ur nyl s Its pl t ocy nide and numb r of salts of the are-e rth el ment

Activators The de elopme t of a large number f in rg n c ph sph is d e to the di c ry that rta n impu ties, lled tivat s, whe present in mount ng g from few parts per million to al p r ce t can confer l minesce t pr perti on the comp nd n wh h they inc p t d (h t o m t ix comp unds) Mang n e is a part c larly effect e cti at in a w de ariety of m t ces wh n n por t d in am nts ang g f om mall t ace up to the d of sev l per cent. The miss pect um of the e m ane e-a ti ted pho ph s ge ally l es n the green yel l *w or ge sp tral egi s. Other f q ently* u ed acti at are copper s l e thallium lead m chromium t tanium, timony a d ti The m t mp rt t ho t m t rials il cat phos-phates ulfide l ide the alkali hal des and xid s of al ium m gnes um bar m, nd zin P ep ti n of ph pho nd the incorpo ation of th act t is g n ally d e by high t mper t rea t n f well m d finely ground powder f th comp n nts.

In o de fo lt a iolet l ght t p o ke lum e ce a b t c the b tance must b ble t bso b t. Bec f variati s n t bil ty to bso b ltra olet l ght f diffe ent wa e-l gths, m t ial may be n luminescent u de ult i let l ght f one w elength a d tr gly lum nescent u d d fferent w le gth n th *It i let eg n F r a simil r* a ub ta e m y not lum der ultr vi let l ght t all d yet b t gly l m sc t under x y rra d tion

LUMINESCENCE IN ATOMIC GASES

The processe th t ur in l m escen e may b most imply ill t ted n the c of an t m a gas. The t m e t ly in e t in pec fi t te f gy som f which e hown sche-m t ally n F g l Th l we t en gy le el of the t m *E* c rre po ds to th t m t un xcit d or gro d, tate, and the h gher e gy l els, *E* nd *E* ep t electr nic lly ex ted t te f th t m Th t t f th t m f m tat *E* t t te *E* equires th bso pti f a am unt f

Lumen

The unit of luminous flux It is defined as the luminous flux emitted within a unit solid angle (1 steradian) by a point source having a uniform intensity of 1 candle It follows therefore that a light source having an intensity of 1 candle in every direction will be emitting a total luminous flux of 4π lumens

The lumen is also equal to the luminous flux received on a unit surface all points of which are at a unit distance from a point source having a uniform intensity of 1 candle

The output of light sources is given in lumen See CANDLE LUMINOUS FLUX [R C P]

Lumen hour

The unit of quantity of light It is the quantity of light (luminous flux) radiated or received for a period of 1 hour by a flux of 1 lumen Similarly other units that can be used to measure the quantity of light are the lumen second or the million lumen hour

The symbol of the lumen hour is Q The equation is

$$Q = \int F\,dt$$

where t is time in hours and F is the luminous flux measured in lumens See LUMEN LUMINOUS ENERGY PHOTOMETRY [R C P]

Luminaire

An electric lighting fixture wall bracket portable lamp or other complete lighting unit designed to contain one or more electric lighting sources and associated reflectors refractors housing and such support for these items as is necessary

Luminaires for general lighting are classified by the International Commission on Illumination in accordance with the percentages of total luminaire output emitted above and below the horizontal into direct or indirect types with intermediate classifications of semi direct semi indirect and general diffuse or direct indirect

Luminaires for floodlighting or for street or highway lighting are classified according to beam spread or according to candle power distribution patterns for the specific applications See ILLUMINATION [W B B]

Luminance

The luminous intensity of any surface in a given direction per unit of projected area of the surface viewed from that direction The International Commission on Illumination defines it as the quotient of the luminous intensity in the given direction of an infinitesimal element of the surface containing the point under consideration by the orthogonally projected area of the element on a plane perpendicular to the given direction Simply it is the luminous intensity per unit area Luminance is also called photometric brightness

Since the candle is the unit of luminous intensity the luminance or photometric brightness of a surface may be expressed in candles/cm^2 candles/in^2 and so forth

Mathematically luminance B may be found from

$$B = dI/(dA \cos\theta)$$

where θ is the angle between the line of sight and the normal to the surface area A considered and I is the luminous intensity See LUMEN LUMINOUS INTENSITY

The stilb is a unit of luminance (photometric brightness) equal to 1 candle/cm^2 It is often used in Europe but the practice in America is to use the term candle/cm in its place

The apostilb is another unit of luminance sometimes used in Europe It is equal to the luminance of a perfectly diffusing surface emitting or diffusing light at the rate of 1 lumen/m^2 See PHOTOMETRY [R C P]

Luminescence

Light emission that cannot be attributed merely to the temperature of the emitting body Various types of luminescence are often distinguished according to the source of the exciting energy When the light energy emitted results from a chemical reaction such as in the slow oxidation of phosphorus at ordinary temperatures the emission is called chemiluminescence When the luminescent chemical reaction occurs in a living system such as in the glow of the firefly the emission is called bioluminescence In the foregoing two examples part of the energy of a chemical reaction is converted into light There are also types of luminescence that are initiated by the flow of some form of energy into the body from the outside According to the source of the exciting energy these luminescences are designated as cathodoluminescence or electronoluminescence if the energy comes from electron bombardment radioluminescence or roentgenoluminescence if the energy comes from x rays or from γ rays photoluminescence if the energy comes from ultraviolet visible or infrared radiation and electroluminescence if the energy comes from the application of an electric field By attaching a suitable prefix to the word luminescence similar designations may be coined to characterize luminescence excited by other agents Since a given substance can frequently be made to luminesce by a number of different external exciting agents and since the atomic and electronic phenomena that cause luminescence are basically the same regardless of the mode of excitation the subdivision of luminescence phenomena into the foregoing categories is essentially only a matter of convenience not a fundamental distinction

Fluorescence and phosphorescence A second basis frequently used for characterizing luminescence is its persistence after the source of exciting energy is removed Many substances continue to luminesce for extended periods after the exciting energy is shut off The delayed light emission (afterglow) is generally called phosphorescence the light emitted during the period of excitation is generally called fluorescence In an exact sense this

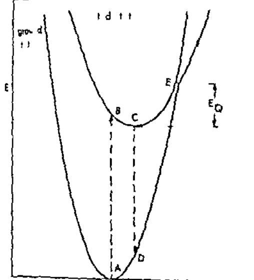


Fig. 2 C fig t coo d t rves f mpl lum est c t r T to $A \to B$ h w b p- ton nd tr t $C \to D$ h w m Th gy E_Q th t ry f r th t d t te t ch th point E f m wh ch t t t th g d t t an be d w tho t l m

curves the n gy of the gr d a d e ited tate is sh n to y parabolically as some fig ra tion oo d nate, us ally th di tance f m th lumi esc t t to it n e t ne ghbor ha ged There is l e f the c ord ate for wh ch th en gy is m im m b t thi value d ffe ent f th gr nd a d e ted tat s because f the d ff r ent int a t o f the lumi e t cente with its n ghbo s. Absorpt on of l ght g es ri e t th tra t f m A to B Th t t oc urs so p dly that the o ar d the l mi c nt ce t do n t h e time t r ar ge. Once the yst m at B it gi es p he t e e gy t its urr ding by me l l tt ce b at ns and reach s th new equil b um po t o t C (e LATTICE VIBRATIONS) Em ssio oc h th y tem mak the t n i tio f m C t D and e agai h t ene gy i gn p h n th sy tem g es f m D b ck down t A It t th l ss of en gy i th form of he t hich uses th e ergy a soc at d w th th em s- sion $C \to D$ t b l th n th t soci t d w th th bsorpt $A \to B$

Wh n the y t m t at n q libr um p it such C f th ted tat urve t s t t re b t m g t er a mall eg n arou d C be e f th th rm l gy f the sy tem At high t mpe t th e fl tu t e a ... of co figu ti n coord te A a e- ... th g d t t urv b t er a reg ... d D In th n ty f D th g d t t ... h rap d g f rgy so th t ... fo the figurati oor ... ge r g t e g e n the

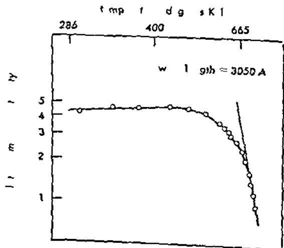
pt cal tr n ti n This explain the broad emi ion and abso pt on bands that are bserved An an ly si of th so t p edict th t the widths of the band (usu lly mea u ed in energy nit bet en the p int at which th emi on or ab orption is half its m x mum v lue) hould v ry s the qu re oot of the temperature For m ny sy tem th s relat n ship is al d f temperatures ne r and above ro m tempe tu

Two oth r phen me a which can be explai d on th bas of the m del de cribed n Fg 2 are temperat e que ch ng of lum nescence and the ar tion f the de ay t me of lum e cence with temperat re In Fg 3 a urve f temper ture qu ncl ing fo the m ion in thallium ct ted p ta um chl ide is hown At low temper t res there is ry little change in b ight ss with t m pe ture but t ele at d tempe atu the lum nes- ce e d cay rapidly On the hem of Fig. 2 thi interp eted s m an g that the thermal vibra tion be me ffi tly inte se t rai e the system t point E F om poi t E the sy tem can fall to th g nd tate by emitt ng sm ll am nt of heat, or fra d r diat n If point E is t an nergy E_Q abo e the m nimum of the excited st te curve it may b h wn that the effic e cy η f lum es- cen e i gi e by

$$\eta = 1 + C e p(-E_Q/kT) \qquad (1)$$

whe C a co tant k is B ltzmann s co tant, a d T the t mpe ature n the K lvin cale By fitt g an expre n of thi f rm to the data f Fg 3 a al of 0.60 elect n lts is f u d for E_Q

Th t mpe ture q nch ng tend t ccur m t st o gly f cente that would h stayed the excited tat f r a lati ely l ng pe d of time A a e lt the d cay t me f the emis n th t c u in th tempe atu e r ion s l g ly har acter t of nt rs n wh h t a sitions t the gr nd t t ha e been r p d the ef e th decay t m of th l min ce i b rv d to dec e e



Fg 3 V t f th b ght f th ll m-a ti- ted p t m chl d ph ph w th t mp t

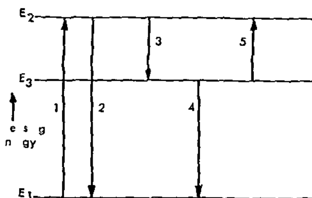


Fig 1 Schemat c rep esentation of energy levels a d electronic t ans t o s n an atom c gas E_1 g ound state E_2 and E_3 excited states 1 excitat on 2 em s sion of r sonance luminescence 3 ad ationless t ansi t on to lower exc ted state 4 lum escence miss on f t ans t on $E_3 \rightarrow E_1$ is allowed (if it is not allowed 4 does not occur and E_3 is called a metastable state) 5 st mul t on of atom back to em tt g state

energy $\Delta E = E_2 - E_1$ If this excitation is to be produced by the absorption of light the energy of the acting light photon $E_{\text{bso bed}}$ must equal ΔE The frequency of the exciting light must therefore be $\nu = E_{\text{bso b d}}/h = (E_2 - E\ )/h$ and the wavelength of the exciting light must be $\lambda_{\text{bso bed}} = hc/(E_2 - E\ )$ where h is Planck s constant and c is the velocity of light In an i olated atom this extra energy cannot be dissipated and is emitted as radiation when the atom eventually returns to its ground state The emitted light will therefore again corre pond in energy to ΔE and will have a wave length $\lambda_{\text{mi ted}} = \lambda_{\text{bso bed}}$ When $\lambda_{\text{mi ed}} = \lambda_{\text{bso bed}}$ the emitted light is sometimes referred to a re o nance luminescence or resonance radiation For further details *see* ATOMIC STRUCTURE AND SPEC TRA

If a large number of atoms are excited and the excitation then removed the lumine cence inten itv will decrease with time exponentially according to the equation $I = I_0 e^{-\ t}$ where I is the intensity of luminescence at a time t after removal of the excitation I_0 is the intensity at $t = 0$ and τ is the avera e time required by an atom to make a spon taneous luminescent transition The quantity τ_l is independent of temperature and it is this tempera ture independence that is emphasized in the more preci e definition of fluorescence gi en earlier If the transition between the energy levels E_1 and E_2 is highly probable (a so called permitted or al lowed transition) τ_l is very small of the order of 10^{8} ec for transitions involving vi ible light

The excited atom can also lose a certain amount of energy and fall to an energy tate E of inter mediate energy between E_1 and E_2 This can hap pen for example if the excited atom collides with another atom If the transition from state E_3 to the ground state E_1 can occur with a rea onably high probability fluorescence will occur starting from this intermediate excited tate In this ca e the fluore cent wavelength $\lambda_{\text{mi i d}} = hc/(E_3 - E_1)$ Since $(E_3 - E_1)$ is maller than $(E\ - E_1)$ the fluore cence in this case will be of longer wavelength than the re onance radiation

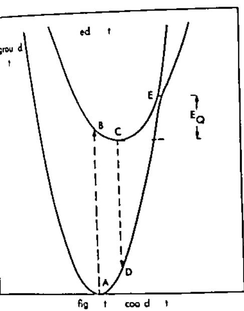
If however a transition between tate E_3 and tate E_1 is highly improbable (a o called forbid den transition) tate E_3 is known as a meta table tate The atom can remain in this tate for long periods of time and cannot return to the ground state with the emission of radiation Lumine cence can occur under the e circumstances only if the atom regains the energy $(E\ - E_3)$ by a colli ion with another atom or by ome other proce s Once the atom has been brought back to tate E a transition to the ground state is again allowed and luminescence corre ponding to $(E\ - E_1)$ will be emitted The exi tence of meta table tates like E_3 explains the delayed emi ion termed pho phore cence The atom may pend a con iderable amount of time in such a state before ome external in fluence causes it to return to an emitting tate uch as E_2 in which ca e the lumine cence is correspondingly delayed and appears as an afterglow In order for the atom to get from E_3 to E_2 it mu t absorb energy somehow The rate of return to the emitting state and hence the duration of the after glow will therefore depend to a very large extent on temperature At high temperatures the atoms will be excited back to the emitting state rapidly and there will be a bright afterglow of hort dura tion At lower temperatures the atom will be rai ed back to the emitting state very slowly and the afterglow will be of long duration but of low in tensity This temperature dependence is the ba i for the more preci e definition of pho phore cence given earlier

The principles illu trated in the foregoing di cu sion may be extended with little modification to the case where the primary ab orption or excitation act completely removes an electron from an atom (that is ionizes the atom) in tead of merely rai ing the atom to an excited state Under the e con ditions the electron can be trapped temporarily by other atom and its return to the parent at m can also be delayed by this mechani m

CONFIGURATION COORDINATE CURVE MODEL

Luminescence in atomic ga es is adequately described by the concept of at mic pectro copy but luminescence in molecular ga es in liquid and in solids introduce two major new effects which ne l special explanati n One i that the emi i n l an l appears on the long wavelength (low energy) ide of the ab orption band the other is that emi i n and ab orption often show as ban ls hundre ls f angstroms wide instead of as the lines f und in atomic ga es

Both of the e effects may be explaine l by u ing the concept of configuration c r linate cur e il lustrated in Fig 2 As in the ca e of atomic ga e the ground and excited tates repre ent lifferent electronic tates of the lumine cent e ter that i the region containing the at m an l/ r le tr ns involved in the lumine cent tran iti n On these



g. 2 C fig t oo d t rv s f a mpl esc nc t T t $A \rightarrow B$ sh w b rp- on, nd tr nsiti $C \rightarrow D$ sh w m Th gy g th t ec sory f th ted t t t h th o t E f m wh ch t t t th g d t t an be mod w th t l m sc

urves th e gy of th gr d a d exc ted st t sh n to ry pa bol lly som fig ra to coo di ate, u ally the di tance f m the l mi nesc t e t t it re t neighbors, i hanged Ther is a al e f the coo d t f r wh l the energy is a mi im m b t th l e d ff r nt f r th ground d e t d t te bec u e f th diffe ent inter ti f the l m esce t ce te with t ghbors. Abso pti n f l ght gi es r e t the tran tio f m A t B Th s tra sition occu so rap dly th t the n aro d the l m sc nt ce t do n t ha tim t earr ge. O e th y tem t B t gi es p he t e e gy to ts d ng by m f latt e b at a d he th ew equilib um po t o t C (LATTICE VIBRATIO S) Emi occu s h n the y tem m k the t i tion f m C t D d nc gai h t e gy is gi en up h th sy tem goes fr m D b k d wn to A It thi l f gy n th f rm f h t hi h ca ses th e gy so ted w th th mis- n $C \rightarrow D$ t be les th th t soc t d w th the absorptu $A \rightarrow B$

Wh the y t m at a eq l b m po ti n h C f the ted t te rve it t t rest b t migr tes m ll eg d C bec se f th th rm l gy f th y tem At high t mp tur the fluct t nd g f figu t n oord te. A e- sult, th emi tr t t j t t p t D th gr d t te rv but g und D I th ty f D th gr d tat rv h w a p d h g f ergy th t m ll ang f l f r th o figur t di t l d i l ge g f n g e in th

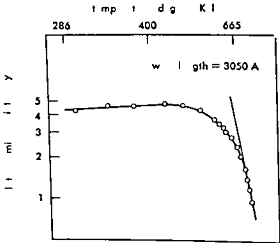
j t c l tr nsit n Tl explai tl e br ad mi i n d absorj t n b nd th t are b r ed An a ialy is f th sort j redi ts tl at tl e w dth f tl e l and (u ally mea ur l e ergy u it l etwe n the po nts t wl ich the mi i n r ab rj ti is l alf t m im m lue) l ld ry the q re r ot f th t mperature F r many y t m tl i r lat n hip is lid f r temper ture near and abo r m temperat re

Tw tl er j he me wl i h c be xj l in d n tl e b is f tl e m d l l scr b l in Fig are t mp ratur j ncl g f lumin sc ce nd tl e ari ti n f the de ay t me f lum ce e w th t mj er ture. In Fig. 3 a urve f t j rat re j encl ing f r tl e em i n i tl llium ti ted pot ium hl id i l w At l w t mperat r tl r i v ry l ttle cl ange in brightne with t m p rat e b t at l t d t mj e ture tl lumin s- ce de ys rap dly O the scheme f Fig. 2 thi interpr ted s me ing tl t the therr l ilra t n lec me ffi e tly i t n e to r i e tl e y t m t po nt E Fr m point E the y t m c n fall t tl gr und t te by mitt g a m ll am u t f heat, r frared r diat If po t E t an energy E_Q bo e th min m m f the exc ted state r e, it may be l wn that tl e eff i cy η f lumines- c ce gi n by

$$\eta = 1 + C \quad p\,(-E_Q/kT) \qquad (1)$$

where C a c n t t k is B ltzmann c t t and T is tl e t mperatu e n the Kel i scale. By fitting pre f th f rm t the data f F g. 3 a l f 0.60 l ctr n lt i f t d f r E_Q

This t mp r ture que h g te d t oc r m t t gly f r te tl at w ld l tayed in tl e ex t d t te f a l ti ely l g j d f t me A a r lt th dec y t m f tl e emi ion that in th t mp ratu e eg larg ly h r t tic f c t in which tran ti ns t the gr u d t t ha e been p d tl er f e, the de y time f th l minescen e s bserved t decr a e



Fg 3 V t f th b ght f th ll m-a t t d p t m hl d ph ph w th t mp t

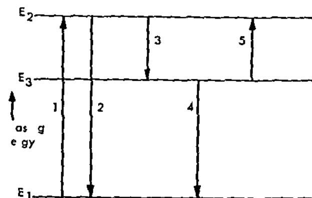


Fig 1 Schematic rep esentation of energy levels and elect onic t ans t ons n an atomic gas E_1 ground tate E_2 and E_3 excited states 1 excitation 2 emis s on of resonance lum nescence 3 rad ationless t ans t on to lower excited state 4 luminescence em ss on f t o s t o $E_3 \rightarrow E_1$ is allowed (f it s not allowed 4 does ot occur and E_3 is called a met stable state) 5 st mulat on of atom b ck to emitt ng state

energy $\Delta E = E - E$ If this excitation is to be produced by the absorption of light the energy of the acting light photon $E_{b\ \ bed}$ must equal ΔE The frequency of the exciting light must therefore be $\nu = E_{bs\ \ bed}/h = (E_2 - E_1)/h$ and the wavelength of the exciting light must be $\lambda_{ba\ \ b\ d} = hc/(E_2 - E_1)$ where h is Planck s constant and c is the velocity of light In an i olated atom this extra energy cannot be dissipated and is emitted as radiation when the atom eventually returns to its ground state The emitted light will therefore again correspond in energy to ΔE and will have a wave length $\lambda_{mi\ \ ed} = \lambda_{bao\ \ bed}$ When $\lambda_{mi\ \ ed} = \lambda_{bso\ \ b\ d}$ the emitted light is sometimes referred to as re o nance luminescence or resonance radiation For further details *see* ATOMIC STRUCTURE AND SPEC TRA

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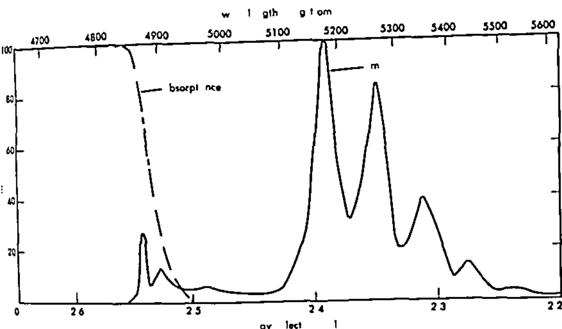
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CONFIGURATION COORDINATE CURVE MODEL

Luminescence in atomic gase is adequately le scribed by the concept of atomic pectr) opy l it luminescence in m lecular gases in liquid an l in olid intro luce two maj r new effect which nee l special explanation One is that the emi i n l an l appears on the long wa elength (lo energy) i le of the al orption band the oth r i that emi i n and absorption often how a l an ls hun lre l f angstroms wide in tead of as the line f und in atomic ga e

Both of the e effects may l e explain l l y i ing the concept of c nfiguration coo r lin te ir e il lu trated in Fig 2 As in the ca e of at mi ga e the ground an l excited tates repre ent liff r nt electronic state of the l imine c nt nt r th t i the region c ntaining the at m and/ l tr n in lved in the lumine c nt tran iti n O i th e

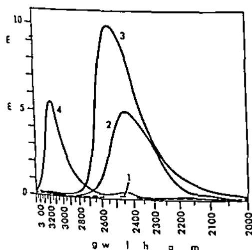


Fg 6. Th bsorpt (100 m p t f t m) d dg m o of dm m lfd t 4 K

bo nd lectr s t low dtele tr c c tant m teri l hile the lo g a g inter t on d m ates for loosely bound lect t high d lect ic c t t mat ials.

SENSITIZED LUMINESCENCE

A p oces f co d bl tere t occu in ys tems here ne type of cti t r abso bs th e u g l ght nd t fer it e rgy t a sec nd type f cti t h ch then em ts. The tran f r doe n t n l m t n of electr Th proce s is fte call d tized l minesce ce, and the principal pho ph u ed i fl oresce t l mp are



Fg 7 Ex t t p t f m g m f l bo t (C CO) ph ph w th d ff t p ty t rs 1 t 2 th ll m 3 le d 4 m

f thi type The r ult n lcium arbo te (CaCO) h wn in Fig. 7 ll trate thi k d f y t m If di l nt mang ese (Mn) al i in porated a n acti t r t CaCO th y t m gi e ly a ry w k Mn m i f r ll wa e l gth f xc t g *ult* let l ght Tl becau e the M i ha ly f rb dd n t ti n in th pectral r gi n h wn by it ry l w bsorpti n t e gth d slow decay f l m esc e. In ther w rd th M d es t abso b ry mu h lt l t l ght Br ght pho ph m y b pr pared by i porat ng di ale t l ad (Pb) m n alent thalli m (Tl) r tri l t eri m (Ce) l g with Mn^{++} in CaCO In a h c e the Mn m s i th ame, b t the w l gth wh ch excite these pho ph rs y s the tl t at (alled the itize) i ch ged All these absorpti ns occ f r ne g well bel w the e ergy t wh h f e lectr e formed the solid Th l n i that th ltra i let l ght i bso bed by the Pb Tl Ce^{++} sen t wh h p ss the en gy to ne by Mn act t s a d exc t the M em

It i imp t t to know ver what d ta s the rgy m y b tran ferred from bsorb r t em t t r E p m ts on calci m ilicat w th Pb^{++} a d M dded mpu t es h e h w th t if M is y e f the 8 nea t latt e t a nd th Pb^{++} the e ergy tra *fer m y* take pl

Th t f f gy h b treat d theo t lly ng q a tum me h d um g a m d l f e o a e b twee pled y tem A n mbe f h e b en ami d i cl e th t h an ll w d tra t n ce ly th c e w ll it abso b the ex t g l ght p pe bly Th fi t e is n wh h the ti t r underg a ll w d tra t The p b-

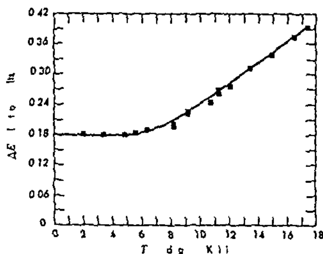


Fig 4 Variat on of the w dth of the F center absorp t on band in potass um chlo ide at ts half maximum points ΔE as a function of the square root of the temperature

Quantum mechanical corrections Although the configuration coordinate curve model of Fig is successful in describing many aspects of lummes cence in solids it predicts that emi sion and ab *sorption* bands hould become narrow lines as the temperature is reduced to absolute zero (0 K) This is not the case as is hown in Fig 4 which gives the width of the absorption band of the *F center in potassium chloride* as a function of the square root of the temperature (An F center is the *simple* t type of color center a color center being a lattice defect which can absorb light For a de *tailed* discussion of the optical absorption bands as sociated with F center s e COLOR CENTERS) At high temperatures the previously quoted results are valid but at low temperatures the width of the band is constant

This phenomenon may be explained by treating the configuration coordinate curves quantum me chanically The curves have the energy versus dis placement characteristics of the simple harmonic oscillator For this case the quantum mechanical analysis shows that there is a eries of equally spaced energy le els separated by an energy of $h\nu$ where h is Planck s constant and is the frequency of vibration The lowest of the e levels occurs at a value of $\frac{1}{2}h\nu$ above the minimum of the classical curve and this energy is called the zero point en ergy Its importance is that even at absolute zero the system is not at re t but varies over a range of configuration coordinates characteri tic of this low est vibrational level Analysis hows that under these conditions the widths of the band ΔE vary as

$$\Delta E = A\,[\coth\,(h\;/2kT)]^{\;/2} \qquad (2)$$

where A is a con tant A curve of this form is drawn through the experimentally obtained points of Fig 4 and hows atisfactory agreement

One other re ult of the introduction of quantum me hanics is that this imple model predicts that both absorption and emission bands should be Gaussian in hape at all temperatures that is, they should be of the form

$$I = I_0 \exp\,[-A(F - E_0)^2] \qquad (3)$$

where I is the emission *intensity* or ab orption strength for light of energy E and I_0 and E_0 refer to corre ponding quantities at the maximum of the curve Figure 5 *shows the* emission pectrum of thallium activated pota sium chloride plotted in *such a way that* the expre sion of Eq (3) would give two straight lines making equal angles with the *horizontal* Although there is some di a ree- ment in the wings of the emi ion pectrum and although the lines are not quite at the ame angle, there still is fairly good agreement with the pre dictions of Eq (3)

Materials with high dielectric constants *The* use of configuration coordinate curve is ju tifiable *only* when the electron taking part in an optical transition is tightly *boun l to a* luminescent center and interacts primarily with its nearest neighbors This appears to be *generally the case in* materials with low dielectric constants such as the alkali halides For high dielectric con tant *materials the* situation is very *different It has been* estimated that for boron in silicon the *electron is pread over* about 500 atoms so that its interaction with the nearest neighbors is mall In the e ca es *the cen* ter interacts with the lattice during an optical transition through the creation of many *vibrational* phonons (sound quanta) at relatively large dis- tances from the center (*see* PHONON) A a e of this sort is illu trated in Fig 6 which shows edge emission in cadmium sulfide near the ab orption edge of the material The major peaks corre pond to an optical transition with simultaneous emi ion of 0 1 2 and 3 phonons re pectively starting with the highe t peak The peaks are equidi tant in en ergy and the pacing is just that to be expected for the creation of phonons

Although both hort and long range interactions of a center with its environment ccur in all ca e the short range interaction d minates for tightly

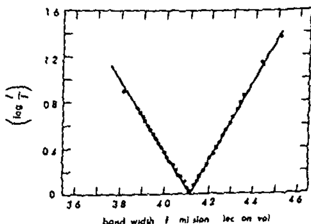
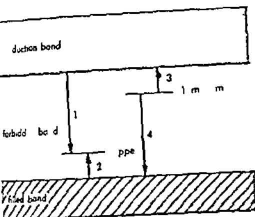


Fig 5 Em s o of th ll um-act v ted potass m chlo r de at 4 K In a pl t of th s f m a G u i n cu e wo ld co ist of two tra ght l es mak g eq al a gle w th the ab ci a



Fg. 9 En gy b d mod l f l m sc p o s inc sulfid w th copp as t ato d lum n m os oactr t r

imp rt nt to n te that n this pr both ele tr ns and h le m t b a med to m

l inc ulfid the mal act ato ar m no lent metal h a Ag r C Tl ey r l c Zn ions. T ma t in electr al n t al ty t nec s- sary also t rporat nt the latt e n uch a Cl r S r Al^{++} f Zn The e add ti al io ar called oa t at rs. Th it ati i w quite c plex, d i illu tr ted f ZnS with Cu a d Al as add d imp ities Fig 9 The ar r m th fig e h w m of tl lectron tran u th t gi ise to b ers ble effect Ar s l a d 4 h w t o d ffe ent l mi esc nt tr t u ns. Arr w 2 h w th itati n f n electr into the l mi sce t e te whi h may oc ur by abso ptı n f f red l ght by th mal flu tua u l e th c e th e ter is pr e ted from lumi esc g a d thu is qu ched Tr n ti n 3 the x ıt ti n of n electr t the du t n b d. The lect m y be it d by th rmal en ergy and ts ppe r ce m y be d te ted b th ppearanc of tr t l Th s p oc c ll d thermol mi esc nce (se THERMOLUMI ESCE CE)

Th de a ty f t an t n a d effects in zin ulfide m kes t diffic lt to ome t firm co cl concerning the d t il f any e y tem At the sam time th ari ty m ke lum ne en e in l ing electron m t n o e f th mo t fa t g nd chall g fields of tudy [C C.K J H S]

B bli gr phy H W Le e enz, *An Int od ct o t th L mi e of S lids* 1950 P Pri gs- h m F l r s n nd Ph sph e ce 1949 F t nd D Tur b ll (d) *S l d St t Phy* vs, 1.5 19 7

Luminosity factor

Th rati f lum fl x t p rt c la wa length to the rre pond ng di t fl x t the am l gth. It xp d l m pe watt. S LUMEN PHOTOMETRY

The lum n ty factor s fte d n th f rm f th lat e lum n ty fa to which i the r t f the lumin s ty f t f a ert wa ele gth to the l t the wa l gth of ma mum l m sity

The Inter t nal C mn i ion Ill i ati n and the Internati l Ci mn itt n W ght and M as re have ad it d alues f r r l t e lumin ity fact r as a ba f r e tabli l ment f i h t met ric ta dard f ty d ffering fr n the primary tandard i e tral di tril uti n f ligl t

Mathemat cally the lumi ity fact r K s f und fr m tl e e juati n

$$K = F / I$$

where F s tl e l nin us fl I is the radi nt flux and λ d ig ates tl e wa l gth

Tl lum er watt is al tl terr i u ed t ex pre the eff ency f an lectric l mp wh h h uld n t be c nfu ed w th lum ity fa tor The eff ency i pre ed as the r tio of tl e tput in lumen di ided by tl e nput in watt [R C.P]

Luminous efficiency

Tl rati of th t tal lumi fl x t the t t l adiant fl x Thi i gen ally tated lumen per w tt f r diant flux L n in ff ien y and lum no ity factor ar ynonym u in tl e ca e wl ere energy i radi ted at ingle w le gth Tl e tl eo reti l max mum po ble l mi ffcie cy f ra d t e gy f a sourc l ligl t e me t a wa e- length of 555 m llim r n (t which tl e hum n eye m t n iti) d i 680 lume s ye w tt b ed n the C.I.E l t p l min ty urv the 1948 Inter ati nal Temperature S al and the n w al e f tl e c ndle S CA DLE LUMEN l HOT M ETRY

Tl e r r al of the l m no ffi ie cy f r di a t en gy i f eq ently all d th mechani l iui lent f l ght

The l min us ffi cy f radiant en rgy sh uld n t be o fused w th th effici cy f an le tric l mp B tl ar gi n n term f lum ns/watt but i th fir t c e the w tt ef r t tl t t l radia t flux wh l in the d th watts ref t the p w ppli d t tl e l mp [R C P]

Luminous energy

The ad ant en gy n the ble reg n It n the f rm of le tr mag et c w e a d nce th sible reg n is mm ly taken as e te ding 380- 60 mill mi o i wa length the l min en rgy i co t in d with n that r gi It i equ l t the time t g l of th pr d ti n f the lumi u flux Se LU IEN HOUR PHOTOMETRY [R C P]

Luminous flux

The t m rate of flow of l ght It i radi t flux in the f rm f l tr m g et wa es whi h ff cts the ey o mor st ctly the t m r te f flow l radi t e ergy e lu ted c rd ng to ts apa ity to p du e al se s ti The i ible spe trum s d narly n d ed t e tend fr m 380 to 60 m llim n n wa l gth th efo e lumin u fl x i d ant flu i th t reg of th electro- m gn t spe tri m Th it f m a f lum n u fl the lum S LU IEN PHOTO IETRY [R C P]

ability of energy transfer P (defined as the reciprocal of the time required for a transition to occur) varies as

$$P \propto \frac{1}{R^6 n^4} \int f F_A dE \qquad (4)$$

Here R is the distance between sensitizer and activator, n is the index of refraction of the host material, which may be liquid or solid, f is a function describing the emission band of the sensitizer as a function of energy and is normalized so that the area under the curve is unity, and F_A is a function describing the absorption band of the activator, also normalized to unity. The integral of Eq. (4) measures the overlap of these bands and determines the resonance transfer. In typical cases the sensitizer will transfer energy to an activator if the activator occupies any one of the 1000–10 000 nearest available sites around the sensitizer. One type of forbidden transition is a quadrupole transition; in this case the number of sites for transfer would be about 100. If the transition in the activator is even more strongly forbidden, quantum mechanical exchange effects predominate and the number of available sites for transfer should be reduced to 10 or less. In both of the cases just mentioned the integral measuring the overlap enters in the same way as it does in Eq. (4). From this theoretical treatment it appears that phosphors with Mn^{++} as the activator probably receive their energy by exchange interactions.

Concentration quenching. Another phenomenon related to the resonant transfer of energy is that of concentration quenching. If phosphors are prepared with increasing concentration of activator, the brightness will first increase but eventually will be quenched at high concentrations. It is believed that at high concentrations the absorbed energy is able to move from one activator to a nearby one by resonant transfer and thus migrate through the solid or liquid. If there are poisons or quenching sites distributed in the material, the migrating energy may reach one and be dissipated without luminescence. Impurity atoms, vacancies, jogs at dislocations, normal lattice ions near dislocations, and even a small fraction of the activator ions themselves when associated in pairs or higher aggregates can act as poisons. As the concentration is increased, the speed of migration is increased and the quenching process becomes increasingly important.

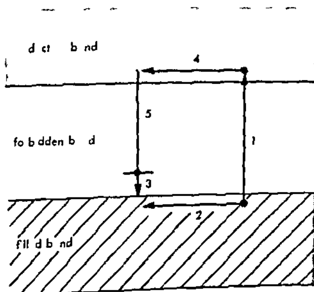


Fig. 8. Energy band model for luminescence processes in zinc sulfide.

LUMINESCENCE INVOLVING ELECTRON MOTION

In an important group of luminescent materials the transfer of energy to the luminescent center is brought about by the motion of electrons. Many oxide, sulfides, selenides, and tellurides are of this type, and of these zinc sulfide has been most widely studied. It is frequently used as the luminescent material in cathode ray tubes and electroluminescent lamps.

Electronic processes in insulating materials are described by a band model such as that illustrated in Fig. 8. The electron energy increases vertically and the horizontal dimension shows position in a crystal. In the shaded area, called the filled band or the valence band, all the energy levels are filled with electrons. No electron can be accelerated or moved to higher energies within this band since the higher levels are already filled. Thus the material is an insulator. Above the valence band is an energy region called the forbidden band, which has no energy levels in it for pure materials. However, imperfections may introduce a local energy level in this region, as illustrated by the short line above 3 in Fig. 8. Above the forbidden band is an energy region called the conduction band. Here there are energy levels, but in an insulator no electrons. If an electron in the filled band absorbs light of sufficiently high energy, it may jump up into the conduction band, as shown in 1 of Fig. 8. The empty position left behind in the filled band, called a hole, has properties which allow it to be described as an electron except that it has a positive charge. Both the electron in the conduction band and the hole in the filled band are free to move and gain energy. As a result, current can flow when a voltage is applied externally. The electron and hole can also diffuse far from their origin and can thus transport energy to a distant luminescent center. See HOLES IN SOLIDS.

A simple luminescent transition is illustrated in Fig. 8. Assume that the impurity level (black dot in the forbidden band) is due to a luminescent center and that there is an electron in the level at the beginning of the process. Transition (1) shows the creation of a free electron and hole due to the absorption of light. The hole migrates to the center (2) and the electron in the impurity level falls into the hole (3), thus destroying it. The free electron now migrates toward the center (4) and falls into it (5), giving off luminescence. The cycle is complete and the center once again has an electron. It

conduction bond

3

I m m

1

f bdd bo d

4

ppe

2

F ed bo d

Fg. 9 En gy-bo d mod l f l m sc c p o s sulfid w th copp ch t d l min m os oct t r

import nt to n te that in this p oc both elec tr d h le m t be a um d t m

In zinc ulfide th n rmal t t are m n f t m tal h a Ag o C Tl ey repl c Zn s T ma t lect al n tral ty it nec s-sary also to in rpo t nto the latt ce n ch as Cl f r S r Al fo Zn Th se add ti al i ar alled t at s. The t t n i w quite plex, and i ill trated f r ZnS w th Cu d Al dd d imp t es n F g 9 The ar r th figu e how som of tl e electron tran t th t gi n e t b rs ble effect Ar s 1 nd 4 h w two d ffe e t l mi esc t t si u ns. A r w 2 h the e c tat n f n le tr into the luminesce t t r wh h m y oc ur by bsorpti n f inf a ed light by the m l fl tua ti ns. f e th r c e the e ter is pr ented from lumi esci g a d th s i q ched Tr n tion 3 the e tati n f elect t the du t b d The l tro m y be exc ted by thermal n gy d ts ppea m y b d te ted by the pp aran f tr ti n l Th s p oc c lled th rm lum n sc nce (THERMOLUMINESCE CE)

The de a i ty f t a t nd effect i zi ulfid makes it d fficult t come t firm l c erni g the d t ils of y ne y tem At the sam time th ar ty m ke l m n scen e i ol ing electr n m t o e of th m t f ting d ch ll gi g fi lds f t dy [C C.K J H S]

Bibl gr phy H W Le e enz, *A Int d ti to tl L mi enc of Solid* 1950 P P ng h m, *Fl or c nc a d Ph pho sc ce* 1949 F Se tz nd D T rnb ll (d) *S lid St t Phys ics*, ol. 5 1957

Luminosity factor

Th t of lumin u flu at a p rt c la w e length to th co resp d g d a t fl at th am w el ngth. It xp ed l m pe tt S LUMEN PHOTOMETRY

The l min ty f t s often d th f rm f the lat e lum ty f t wh h th t o f the l m s ty f to f ert in w ele gth t th l at the ngth f m im m l m ty

The Internati nal Comn i n Illumi ati n an l tl e Intern ti n l Comi itt i W ght and M as-ure have ad pt d alu f r rel ti e lumin ity f ct s as a l f r e tabl hm nt of l t m t ric tandards f type d ffering fr tl e pr mary t ndard i pectral di tr buti n f light

Matl em ti ally tl e lumi o ity fact r K s f und fr m tl e e juati n

$$K = F / I$$

where F is the l min us fl x I is the radi t flux and λ desig tes tl e wa l gth

The lum n per watt i alsi tl e term used t ex pre the eff c ency f an l tric l mp wh ch l uld n t l e c fu ed w th lum n ity f t r Tl e eff ncy i e pre sed as the rati f tl e tput in l men di id d by tl e n put, in watt [R C P]

Luminous efficiency

Th rati f th t tal lumi us fl t tl e t t l radiant flux Thi i gen r lly t ted a lumen per w tt f r d ant flux L mi us ff cien y and lumi n ity f ct r yn ym u n tl e ca e wh re en gy i r di ted at ingle wa el ngth Tl e theo-retic l max mum p ible l min s ffic e y f ra d a t e rgy f a so rce f light c me at a w le gtl of 555 m llim ro (at whi h tl e h m n eye m t se iti) d is 680 l m s pe w tt b ed the C.I E. pl i p l m n ty c rve the 1948 Inter ati nal Temperature Scale and tl e new al e f tl e c ndle S e CANDLE LUMEN PHOTOMETRY

The rec proc l f tl lum n effi iency f r di ant en gy freq ently c lled the m ch ni l qui lent f l ght

Th l min efficiency f rad nt en gy h uld not be nf ed with th effi ie y f an lectri lamp B th gi e in term f l men /watt but i the fi t a th w tt refer t th t t l rad a t fl x wh le in the se d se the watts ref r t the p w ppl d t th l mp [R C P]

Luminous energy

The d nt gy the i ible r g n It n th f m f le t om gnetic wa e and n e the i ble regi n commonly tak n xtending 380– 60 mill mi i w elengtl the lumi us ergy i nt in d w th n th t eg on It is eq al t the time i teg al f the produ t n of the l m n us fl x Se LU IEN HOUR PHOTOMETRY [R C P]

Luminous flux

The time r te f fl w of l ght It i r diant flux th f rm f le tromagn tic wa e wh h affe ts the e e r m e t ctly the time ate of fl w of radi ant n gy l ated a c d ng t its c p c ty to p d ce u l en at n Th v ble p ctrum rd r ly n ider d to e tend f om 380 t 60 m llim on i w elength the ef e lum no s flux di nt fl x n th t egi n f the electro-m gnetic sp ctrum The t f mea re of lum s flu i the l m n See LUMEN PHOTOMETRY

[R C P]

Luminous intensity

The solid angular luminous flux density in a given direction from a light source It may be considered as the luminous flux on a small surface normal to the given direction divided by the solid angle (in steradians) which the surface subtends at the source of light Since the apex of a solid angle is a point, this concept applies exactly only to a p int source The size of the source however is often extremely small when compared with the distance from which it is observed so in practice the luminous flux coming from such a source may be taken as coming from a point For accuracy the ratio of the diameter of the light source to the measuring distance should be about 1 10 although in practice ratios as large as 1 5 have been used without exceeding the permissible error

Mathematically luminous intensity I is

$$I = dF/d\omega$$

where ω is the solid angle through which the flux from the point source is radiated and F is the luminous flux *See* LUMEN PHOTOMETRY [R C P]

Luminous paint

A type of paint that glows in the dark. Luminous paints may be either of the self luminous type (energized by a radioactive salt) or of the type that requires excitation from an outside energy source such as light. Both types are made by incorporating luminescent material into the paint formulation.

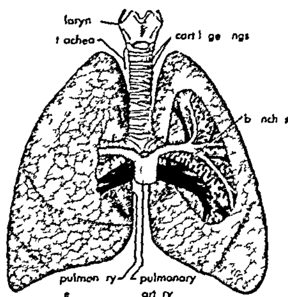
The self luminous paints glow continuously for several years and are used chiefly for painting the dials of watches or compasses Zinc sulfide type phosphors are generally used in their preparation, along with traces of some radioactive salt such as radium bromide or mesothorium bromide Excitation of the pho phor is principally by bombardment of alpha particles (nuclei of helium atoms) from the radioactive salt or from one of its decay products.

The paints that require an outside source for excitation may be classed as either short afterglow or long afterglow paints The luminescent materials in the short afterglow or fluorescent, paints are generally organic polynuclear hydrocarbons like anthracene or chrysene, or various luminescent dyes such as rhodamine Long afterglow or phosphorescent, paints generally employ either alkaline earth sulfide type pho phors or zinc sulfide type pho phors The former type give distinguishable luminescence f r periods up to 10 hours while the useful afterglow of the latter type is generally limited to 1 hour or less These paints are used, for example, under blackout conditions during war time For painted arrows or signs on a wall it is necessary to have an extremely bright afterglow for a relatively short period of time.

[C.C.K. J H.S]

Lung

In man the paired respiratory organs in the chest, separated by the heart and mediastinum The right lung has three lobes the left lung, two A bronchus an artery and a vein enter each lung at the hil im each branches again and again to form lung lobules and smaller divisions The terminal airways or bronchioles expand into small clusters of grapelike air cells or alveoli The alveolar walls consist of a single layer of epithelium and collectively present a huge surface A small network of blood capillaries in the wall of the alveoli afford exchange surfaces for the diffusion of gases



The human lu g (From T I Stor r a d R. L. Us ge Gen ral Zoology 3d ed McG aw H ll 1957)

A serous membrane the pleura covers each lung and is reflected over the adjacent walls as the pleura

Lungs are simple sacs in those fish that ha e them and in reptiles and many amphibians only birds and mammals have developed the complex warm blooded respiratory system similar to that of man *See* LUNG DISORDERS [E C ST]

Lung disorders

Diseases of the lung include inflammatory proce se due to infecti ns processes of scarring and destruction which reduce the respiratory surface of the lung, disturbances of pulmonary circulation and tumors The lung can also be affected secondarily by extensi n of bronchial diseases (*see* BRONCHIAL DISORDERS) For a general discussion of the effect of pulmonary diseases on the whole organism *see* RESPIRATORY SYSTEM DISORDERS

INFLAMMATORY DISEASES

These diseases can be acute or run a chronic course they are usually accompa ied by fe er

Pneumonia This is an acute inflammat ry disease of the peripheral air spaces of the lung cau ed

y infection from ar ous pathogen c microorgan .ms. The type of p e m nia is larg ly dete mined y the infect ng agent, which reaches the pulmo- ary al eoli through the a r ays Pneum nia is a ra e disea e, ma y f rms ha ng a h gh mortal ty ate.

Lobar p umo ia Th s is the c mm e t f rm to h h th t rm p e monia i appl ed without peci ic tion. It is ca sed by the gram po iti e pne mo- coc s, *Dipl c c us p eum e* Infect n by p umococ i u es p eumo a only if the re- sistance f the pat ent aga t inf t n is mark edly l ed by uch ditio as chill p found f tigue, sev e inj i s r many se i us d e ses particularly those ssoci ted with fa lu e f the ght he rt. The i fectio tarts in one ea and p d p dly th ough ut an ent re lobe of the l g. Th fi t de e of ti ue rea ti n is con gesti n f the al eol r cap llar e wl h fill with blood an exudat n f pl ma to the al e li th th bseq nt add t n of leukocytes o white blood ells f llo s. This exudate l ts when fibr f m ti n oc urs. The norm lly pongy lung tt ns r firm l rl ke c te y The pleura becom l ed d some ex date w th fil rin n ad the pleu al c ty The le kocytes a e ble t na ti te, allow and de t oy the pne mococ i if they ha bee p evi ly made le s ggre i e by the acti f ant bodies, formed i the body r by th py ith s lf n m des or a tib ot s (e PHAGOCYTO IS) Re t tut n t ke pl e thr ugh liq fa t n f th cl tted xud t and rem al f th fl d by th lymph tic nd blood es l S no ti u d tr y d the p ti n f the l g ti u is u.u lly c mplet ly e t red w thou t a y re id a I are insta s, the exudate is replac d by on necti t u r an bsce f rms

Focal pneum nia B ch p eum ni r focal pn um ni s ca sed by trept c cci st phylococci d p eumoc c *Kleb ll p m n* f e q ently mpli t g oth di ses, es a type f pn m n a h ch ft n foc l b t n l o be l h r h as F edl d r pn um ni D s- eminating fr m the maller bronchi br ncho- pne ionia tends to de troy ti ue and to f rm ab ce e Heal g re ult in scarr ng r f rmati n of n encap ulated ca ity The e ases often ha e a high fatality Tl e m rtality rat for Fri dl nder pneumonia wa 80% and despite antibi tic is still al ut 0%

I ter tit l pn um ia This di a e is character i ed by e n e ti n of the al eolar capillaries and a cumulat n f fl d a d leuk cytes in tl e loo e nnecti e tis i e f the lu g It i u ually found in infection cau ed by iru r k tt ial rgan ms, or imilar p tl og

Pl risy Pleur y r pl uriti i an inflamm ti n f tl e pleur acc mpan ed by fluid a umulat n in tl e pleural ca iti It occurs n m ny d sea e f the l g p rticularly in tuber lo Tl e l lood essels f the pl ura be me cong ted fluid n t ining pr t n and wl ite blood cells e cap s fr m the cap llarie a d a um l tes fir t i the nnec ti e t sue F m there it pa e thr ugh the lining lls f the ple ra int the pl al i e where it ec mulat ch fly i the pace between the dia ph agm nd tl e che t w ll F brin d p ted n the pl ural surfa es The ple r l effu i n can be r m ed ith as th rapeutic me re r f r di gn tic p pose by in ting a eedle thr gh tl e he t w ll E min ti n f the fluid r eals p ll b cteri r tum ll p inting to the ti l gy f the pl ur i If th inflamm ti n the fl id i re bsorbed Tl e fibr n ered urf ces f lung a d hest wall tick t g ther n ecti e ti e a d blood l gr w thr ugh th dh i a d bl t rat the pl ur l p ce A m e fl i ca bec me p rul nt in whi h ca e a thi k p le of fibr u t ue f rm bout it Such an cap ulated m f p s i called n empyema.

Pulmo a y t b r ulosis Th s i a inflamm tory dise e of th l g due t nfecti n l y th tul e cle bac ll *M y b t m t b r ul s* a gram p ti a d l t rod The pathway f r nfect on r lly thr gh the airways. Th primary s te f t l l i i m t c the lu g, whe e a loc l z d nflammat ry nod le f spec fic truc t r tl t ber le f und Th i fect n tra els thr gh the lymph s ls nd r che the regional l mph n de wh ch be me ll n Th s so-call d p m mpl x f t be l n ofte be e b x) (F g 2) Immu ty aga n t th t ber le b ll des l ps gr d lly n m t pe s ns Heal g f the pr mary le o s lea e m ll l ified ar The l ngs agai be ff ct d by ec d a t b cul n th d em n t d m l ry f m with h ndred f mall t b r le r n the l al d a o s f rm in wh ch t ue i pro- g e l d i ved so that a tuberc lou a ty ults S TUBERCULOSIS

Scarring and destruction Th n rm l sp nge l k patte f th lung c n be lt red by enl rge ment a i p lm ary mphy ma by c llap e f th r p ce a n tele ta i E t n i e r ng f m h r t t n d t y th pulmo-

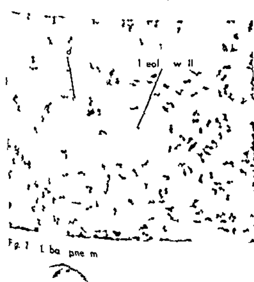
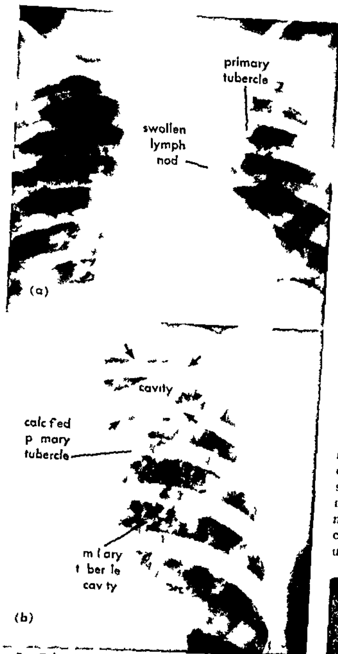


Fig. 1 L ba pne m



Fg 2 T be culos s ( ) P imary (b) P lmo ry

nary structures by formation of strands and foci of connective tissue fil rosis

Emphysema This condition designates two en tirely different diseases In inter titial emphy sema air bubbles are found in tissue chiefly in loose connective tissue where the air can pread easily It is frequently located in the inter tices of the lung and mediastinum having diffu ed from ruptur d alveoli of the lung Pulmonary emphy sema is a state of abnormal distension of th pe ripheral air spaces of the lung The walls of dis tended alveoli are thinned finally leaving large spaces con isting of coale cent adjacent groups of alveoli which have lost their epta (Fig 3) These blebs can reach several centimeters in diameter and are then called bullae resulting in bullous emphysema This is due to air trapping in periph eral parts of the airways when air enters the e air spaces on inspiration but is prevented from being expelled during expiration by a val elike mecha nism in the small r bronchi In diffuse pulmonary emphy ema a large number of slightly disten air spaces is encountered throughout the lung can occur when a part of the lung has either und gone atelectasis or has been removed surgically minor form is quite common in older individu Emphysema patients uffer from severe hortn of breath since many alveolar capillaries have be destroyed with the alveolar walls The respirato surface of the lung is significantly reduced and t blood is incompletely oxygenated resulting in cy nosis

Atelectasis In the adult lung this condition the collapse of the air spaces through ob tructio of a *bronchus* by tumors foreign bodies or othe conditions The retained air is absorbed by th blood Compression of the lung from outside b tumors also leads to atelectasis (Fig 4)

In congenital atelecta is expan ion of the lung is partly or completely prevented at birth for vari ous rea ons and the air spaces cannot become filled with air Complete congenital atelectasis is *fatal and* accounts for the death of many newborn children

Pneumoconiosis This is a general term for a group of diseases of the lung induced by various kinds of dust which results in focal scarring They *mostly* represent occupational disea es ince the exposure to the particular dust has to be exten sive and of long duration The most important agent is silica which is inhaled by miners stone masons *metal* grinders sand blasters and others and which causes silicosis Most of the inhaled du t is coughed up however the particles which reach the alveoli



Fg 3 Pulmo ary emphys ma

are t k n up by phag cyt d dep it d i the te tiu l t u f the l ng whe th y u e mt u The t e rea ts by f rm ng a c p ul ar d the rr t ting f reign bdy Si e the i r tatio does t e e um r mall f rm d le f rm h h are scattered th ugh ut the l ng By c les en e f the e n dule la ge a ea f the l g bec me fib tic fin lly reduc g the b atl ng pa ty gn fi tly a d res lt g in h t e f br th T be l i i f qu tly a c t d with ilicosis.

CIRCULATORY FACTORS

D se ses f the lati pa t ul ly l art diseases, h e the fl e n p lm nary ircu l ti d h e on tl l ng Th re p rat ry f c ti m t ffect ly di t rbed ften w th a ud den unexpected nset S CIRCULATION DI RDER

Pulmonary edema Th is an cum lat n f bod fl d th l g Se m e c p f m th c pillaries mul tes fi t in the lo e c nect e ti e f th al eolar wall d then p e t th pa es d d pla es the air The flu d nt n ing p t in m ed w th fi e ai b bbles a a es lt f esp t n and f rm fr th whi h gr d lly p hed i to the l r nch d can ppea th m th. Lo d b bbl g s he d resp a ti n. The p t t h w h rt e f bre th and cy ti h t lly d w g in l ow fl d (F g 5)

P lm ry ed m ca b c d by loc l p oc esses h h r a e the perm b l ty f th pil laries f r fl d Th s th flamm t h sp m a, nd po so g by t xi g partu ul ly ch ar g e ph g Th m t mm e f p lm ry dema i a p ll ry blood p es e, h ch ctually q the fl d t f th es l Th oc wh n th l t h art fail t f lfill t f nct wh l the ght h art ha ret d m les rm l ffi e cy T mpo arily m e blood p mp d t the l g th n s d ai ed t, e lt g e g g me t f th pulm ry e d p ll r e d p f fl d t the l lt Th ca d l p y r p dl Th m t ff ti e t tme t f th typ f p lm n ry d m t ll c ts f p nct re f

Fig 4 At l t

Fg 5 P lm ry ed m

ein w th letti g f bl d t redu e th lt fl l d p mped t th l ng

Pulmonary infarct Th i re lt in a destr ti n *f a p rti n f th l ng d t the dd n l f a b h f th p lm nary t ry by l dg* ment f thr mb s. Thr mbi lly f rm in a ften i r f th e th gl nd e el sed d di pl d by the l l d tr m t th p lmo n r rtery wh e they c l d m ll r l ranch Death f t e c u ly if the l ng alre dy d maged by th r di e e g t d edem b failur of th l ft he rt Ti e ecr i pre nted he lthy lu g l y th ll t l l l d upply fr m the b hial art rie An infar t i wedge h ped a rd g t th d t l t n f th b he f th oc l ded e el It has a firm d k ed ppe r e, d t bl ed g t th ti ue Patient w th large i f t ft n c mb wh le *malle inf t h l by sca ring*

Tumors of the lung I m ry t m f the lu g a e m tly l ated in th l nchi and lud b nch l d ma a d br nch g in ma The lin g ll f the al eoli g e ri e t pri m r al l ll a m wh h i r l ti ely r e. Tum f the pl mesoth l m ta gr w t the lu g ti u

The l g i f equently the prim y te f me t t f m t m rs of oth r g ns wh e lus t f er cell penetr t t th i d r arr ed way by the bl od t eam wh ch b ing th m i t the l g S e th y e t b g t pa th gh the l eol r cap ll th y e h ld b ck d c t ue th r be t gr w th f rm g w *tum* wh h de tr y th l g ti [E WE]

B bl g phy S RESPIRATO Y SYSTEM DIS ORD RS

Lungfish

A m mb f th p der D p The l ng fi he w f rm ly b d t a d the e e m f l f rm d t g f b ck th D i Th y w l m t d t th g era e h w ll l t d f m t l t The mbl dd r l g l ke a d d l y p at y d e,

with or without gills which are also present The lungfishes are slender elongated fishes The premaxillae and maxillae are lacking and the teeth are specialized into crushing structures called tritorial plates

Neoceratodus fosteri the Australian lungfish is the heaviest bodied of the three It has large cycloid scales sturdy short paired fins and a relatively deep body It now occurs only in the Burnett and Mary Rivers of Queensland This fi h u es its lung as an aid to breathing in stagnant water It does not estivate

Lepidosiren a monospecific genus of South America and *Protopterus* of Central Africa are similar They have slender bodies small scales and long very slender paired fins They live in seasonal swamps and move about over the bottom hunting mollusks during the wet season breathing primarily if not entirely by means of their gills During the dry eason they form a mucus lined cocoon in the mud in which they estivate During this period respiration appears to be entirely through the lungs They escape from the cocoon and resume activity with the return of the wet season There are three species of *Protopterus* See DIPNOI

[J D B]

Lupine

A cool sea on legume bearing digitate leaves with five or more straplike leaflets and having terminal racemes of pea shaped blossoms

Three pecies the blue yellow and white named for the color of their blossoms are used in field planting Lupines need much less potash and lime for growth than the clovers They do not tolerate extremely low or high temperatures and are attacked by numerous diseases and by several insects

The older varieties of lupine contained a bitter toxic alkaloid and were used only as cover crops However since 1912 European plant breeders have selected low alkaloid varieties of blue and yellow lupines which can also be u ed for forage

The production of blue lupine as a cover crop increased greatly in the southeastern United States beginning in 1939 Since 1951 however lupine culture has declined partly as a result of an increase of disease and insect injury See BREEDING (PLANT) COVER CROPS LEGUME FORAGES [P T]

Lupus erythematosus

One of the collagen di ea es in which connective tissues show a similar form of biochemical and structural alteration Each of the collagen disea es is a distinct clinical and pathologic entity and such a grouping exists more as a matter of convenience than because of a common etiologic factor See CONNECTIVE TISSUE

Collagen diseases display three local forms of degeneration inflammation namely fibrinoid mucoid and hyaline degeneration Each has its own histologic appearance and may occasionally be seen in other diseases The causes are poorly understood but hypersensitivity and nucleoprotein derangement appear to be involved See HYPERSENSITIVITY NUCLEOPROTEIN

Lupus erythematosus is an acute or subacute febrile disease that may produce wide pread damage to the connective tissue components of many organs and tissues It occurs predominately in young women but males appear to be increasingly affected perhaps because of development of better diagnostic procedures The blood vessels heart kidneys skin and serous membranes are characteristically invol ed One of the most triking findings in more than half the ca es is the appearance of a reddish butterfly shaped ra h over the cheeks and nose (see illu tration) A blood serum factor is present in lupus which produces almost pathognomonic changes in the blood neutrophiles

There is a significant incidence of involvement of the heart (myocarditis) and also of the lining and valves of the heart (endocarditis) Kidney lesions (nephritis) and lesions of the serous membranes of the heart (pericarditis) lungs (pleuritis) and ab





Lupine (a) Plants (b) A field of lupine in flower



pus ryth m t (W A N D I d Am
l strot d Med J D ct y 19th d S d s
1942)

domi al perit ne m (p rito t) are c mmonly enco tered Small arter s bec me the ite f r n flamm tory rea tio s, e pe i lly in the k dn y
Th clinical p ture is q ite ar ed dep e di g th rgan n l ed A ir egul r fever i m st char t t c, d the patie t mo e ill than tl e ph al fi d g ld i d c te W akne w ight loss, m tal aberr t on a d k dn y or he rt c m pli ti ns omm n Lup s ften mimi s th r dise ses bec e of the w de p ibility f ti u dam ge. De th ually e es w th n 2 5 years fter an intermitt t ill ess ma ked by c se and p gressi e dete ti
D e d l p s s common kin di a e that el d m p ecedes di em at d lup s m ny a th i ties d the t to b ep rat di a s ti ly Oth r coll g di ea es clud p ri rte-tis odosa, dermat my it a d le od rma Rh um tic fev he m t id rth tis, a d rum sickn s, as well s c rta n th r d seases may b incl d d in th t g ry Ea h of the d sord rs ha ts n pecul arit s, l cal c se, d pr gn
S e RHEUMATIC FEVER [E G.ST]

Lutetium

Eleme t umber 71 l t t m Lu is ry e il and the hea t membe f th r e- rth p Its at m e ght i 174 99 d the tu y occurring el m t s m de up f th t bl

sot pes L 97 41% a d L 2 59% It w d sc red n 1906 by G U bai who n med t l tec m, ft c t n m f P It w lso disco ed d p d tly by C. F A r

Welsbach wh named the element cassiopeium but lutetium is the accepted form at pre ent The salts are colorless and give a tri alent ion in solu tion For the propert es of the metal see RARE EARTH ELEMENTS [F H SP]

Lux

The u it of illuminati n when the square meter is taken as the unit of area It is defined as the il lumi ati n on a surface ne q are meter in area n which there is a l minous flux of 1 lumen uni f rmly di tr b ted r the illum nati n n a surface all points of which are at a di t nce f 1 met r fr m a unif rm p nt urce f 1 candle See ILLUMINA TION LUMEN [R C P]

Lychee

The pl nt, *Litchi chi ensis* also called l tch i is a memb r of tl e so pberry fam ly (Sapindac ae) and nat e f so thern Chi a where it h s been lti ated f more than 000 years It i n w bei g g wn suc e fully n India Uni n of South Afr ca Ha a i Bu m Madagascar We t Ind s Brazil H nd r s Japan A stral a a d the so thern Un ted States The f uit is a e- eeded b rry The th n le th rv ugh hell r perica p f the r pe fru t i bright red in l r in mo t rieties Be-n ath tl e h ll a d ompletely ur u di g tl e eed the ed ble a il or pulp The fr it may be at n fresh ca ned r dr ed In Ch na the fr h f uit i c n d ed a gr at del ca y See SAPIN D LES [P D S]

Lychniscosa

An rder f the ubcl s He a terophor in the l He a t n llid The p en hymal megascleres f th se p g a e ted t f rm a rig d fr me-w k Th p ren hymal m ga le a e all r in pa t ly hn se hexa tin in wh h the c tral p rt f the pi le is s rou ded by a ystem f 12 trut E ampl f th rder are *Aulocyst s* nd *D tylo ly* See HEXACTINELLIDA HEXASTERO PHORA [W D H]

Lycopodiales

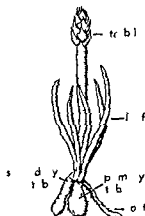
An d r f th pl t bphyl m Ly p ida with a f il hi t ry t d g back to the P l zo c (e GEOLOGY PALEOBOTANY) These plants c m m nly ll d l b m se att d th r greatest d l pme t du ng the Carb f rous period a d n l ded e e l tre l ke f rms mp bl in size w th the p s t d y p (F g 1) T day the r d t ns nly tw ge *Ly p dium* and *Phyll gl s m* comp ed f sm ll herbaceous e g n pla t w th up ght t ailing tems b r g m s mall mple p rally arranged l S me f th t p al sp es are p phytes (li e p rch d la g r pl t) The stem are d h tomo ly b a h d (f ked) In s m p es o e fo k f rm a l t r l b nch wh l th th be-m the ma i Th p phyll (po gi m be ng l a) m y be ggregated together int



Fg 1 Re torat o of Carbon fe ous forest trees an ce tral fe ns club mosses and equi etum (F om E N Transea H C Sampson and L H T ffa y Textb ok of Botany re ed Harpe 1953)

cone or strobile or the sporangia may be borne singly on the upper surface of porophylls scat tered along the stem The cones are often ele vated on upright branches so that they occur abo e the leafy shoots Because the cones resemble a club these plants have been given the erroneous ommon name club mo s The imilar spores (ho mo pores) are grouped in tetrads indicating that reduction division occurs in their formation from the spore mother cells

Classification Of the two genera included in this order *Phylloglossum* is confined to portions of Australia Tasmania and New Zealand (Fig 2) This genus has only one species of simple struc ture which may be the living descendant of more highly devel)ped ancestors The other genus *Lyco podium* has about 180 species and is world wide in distribution The greatest concentration of spe



Fg 2 Fert l plant of *Phylloglos m d mmo d* twice natural s ze (Fr m A W H upt Plant M ph l ogy McGraw H ll 1953)

cies is in the tropics and subtropics but the e plants al o grow in the arctic region Many of the species are perennial and inhabit the moi t wood land or forest floor whereas others are epiphytic and grow upon fore t trees

Structure In most re pects the anatomy of *Lycopodium* especially that of the roots and leaves is like that of other vascular (higher) plants *See* LEAF (BOTANY) ROOT (BOTANY) STEM (BOTANY) The primitive arrangement of the vascular tissues in the stem is called a protostele (a olid cylinder devoid of pith) which may be modified by the relative position and amounts of xylem and phloem in the mature stem (*see* PHLOEM XYLEM) All of the va cular tissue is primary ince it is produced by a cluster of apical meristematic cells with no indication of cambial or secondary activity (*see* MERISTEM APICAL) Development and maturation of the xylem is exarch or toward the center A strand of conducting tissue extends from the stele int each leaf and becomes its vein but no leaf gap is produced where the strand emerges from the stele Similarly each branch and root is connected with th primary tele but in the e case gaps are left in the central cylind r as is true in all va cular plant

Alternation of generations The conspicu us plant with its root stem lea s and sp rangia is the sporophyte r pore producing generation (Fig 3) The sporophyte begins with the yg te (fertilized egg) and ends with the formation of spore The gamet)phyte (gamete pr)du ng gen eratio n) begins with the pore and nd with the union of the egg and erm in the f rm ti n f th zygote In *Lycopo lium* porangia are large and somewhat kidney haped and are borne ingly in

the upper leaf xils. Each sporang um h s a l o t talk and a th k all of e r l cell lay r Wl n mature, t co tai s a m s of mall yellow thi k alled po es. The pores are l berat d thr gh a tr ns rse sl t appeari g n the p a g um wall In this ge s the e is a se es f p ogre t tage am g the m r u peci aryi g fr m tl e ti hich every leaf o the plant is pote t ally a poro- ph ll t th se n wh ch th sporopl yll are agg e gated into mpact ell d ff r nti ted trobili (co es) Acc rd ng t spe ies, the l b r ted p r s ary in th peed w th wh h they ge min te nd d l p t g m tophyte (gamete pr du i g gen t) Many po seemi gly equ re tl e pr s- ence of my orrh zal f gu f r the r co t n d ex ence and mat ratu n (s e FUNGI) In some pe- ies the gam t phyte grow abo e gr u d a d be- come green, hereas n ther pe i tl ey de el p bel ground and a e de o d of chl r pl yll The gamet phyte may be e ther t be o r br l i g It the bte anean types wh h ar fe ted with f gus and r prophyti (l e n d ad o g tter) The se o g s (nther d d arche- g ia) a e l g a d are borne n the t p u fa f th gamet phyte (Fig. 4) Fr m a p rfi ial cell, h ther d m d el p t a o al m f pe m m ther cells wh h p tr de l ghtl l the m ss f g met phyti ti e Th pe m pro- d ed n th anth d um a e f if rm (pi dl haped) d e h ha tw fl g ll attached at th

mbry
th d m
h gon m
hi d
ll w h
f g
( )
(b)

Fg 4 Ly p d m g m t phyte p oth ll s (lte B hm) ( ) Ext l w f l mpy bt g m t phyt (b) L g t d l ct f g m t phyte sh w g h g d th d mbedd d th t p p rt h d o g t th f d c ll t g f g (d k ll) (F m H J F ll d O T pp C ll g B t y H lt d 1954)

Fig 3 Ly p d m l t m ( ) Old p th ll (b) P th ll w h y g pl t tt h d ( ) A th d rt l ct (d) Sp m t d ( ) Y g ch gon m th k t ll l d (f) Op he- gon dy f f rt l i (g) Pl t b g (h) Spo phyll w h p d p g m (j) Sp f tw p t (Aft B hm f m E St b g F N ll H S h k G K t A T tb k f B y 3d d. M m ll 1908)

a te r nd The a h g ia (fem l) re pro- d ed th sam th ll b t ally t w rd the m g s M ny h g n are f rmed b t ly a few d el p aft r f rt l zat In some spe ie e r l n w po phyt may be prod ed f m the ame tl all at nt rv l er ever l ye r Th gamet phyti tl ll p r t nd upplie tri t t th de l pi g p phyt which ent lly be m nt ely self upp ting Th wl l pr f po phyt d el pm nt e y low a d t m t ke e ral ye f r th y ung plant t re ch th rf f the il a d t k the f tur s f th m t pl nt S TRACHEOPHYTA [P A V] *B bl g phy* S LYCO SIDA

Lycopodineae

The ly l f th bphyl m Ly p da It mad p f th fi o d rs t g the Ly o- pod l cl b m e the S lag llales m ll l b m ses the Lep d de d ales r g ant cl b m (f d ly f l) Pleu m l (f d nly f l) a d th I et le q ll w rt Th l g de f th l ss f g fi that th t dy f the r t t r d l f v le p d l t the u d ta d ng f the n w t t p s f p ra a d th me h ng wh h h ed du g the l t n f th p t l d fl (ee PALEOBOT Y) Th tw mo t mm n g a d the e h g th w d t d t b t e *Ly p d m* nd

Selaginella In *Lycopodium* the spores produced by the sporophyte are all alike (homospores) whereas in *Selaginella* the spores are unlike (heterospores) *See* ISOETALES LEPIDODENDRALES LYCOPODIALES PLEUROMEIALES SELAGINELLALES TRACHEOPHYTA [P A V]

Bibliography *See* LYCOPSIDA

Lycopsida

A subphylum of the plant phylum Tracheophyta having a long fossil history but today restricted to four living genera The living members commonly called club mosses (a misnomer) are of significance in that the study of their structures and life cycles provides clues to the understanding of the many extinct species Some of these plants now known only as fossils were the dominant species of the extensive swampy forests of the Carboniferous and grew to 30 meters in height (see GEOLOGY LEPIDODENDRALES PALEOBOTANY PLEUROMEIALES)

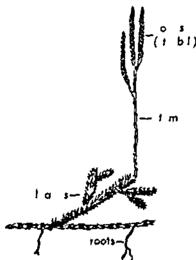


Fig 1 Lycopodium or club moss showing prostrate stem with many small leaves upright stem bearing cones or strobili and roots arising from rhizome (From H J Fuller The Plant World rev ed Holt 1951)

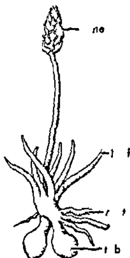


Fig 2 Phylloglossum with fleshy tubers at base giving rise to roots quill like leaves and a stalk with a terminal cone (From H J Fuller and O Tippo College Botany rev ed Holt 1954)

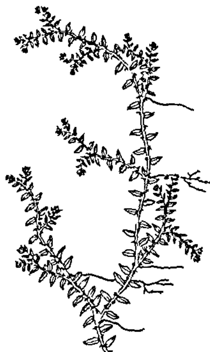
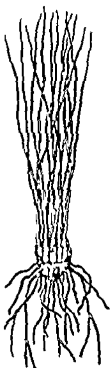


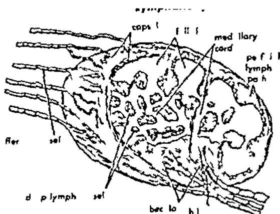
Fig 3 Selaginella kraussiana portion of a sporophyte (From G M Smith Cryptogamic Botany vol 2 2d ed McGraw-Hill 1955)

Classification The living members of this subphylum are confined to the four genera *Lycopodium* *Phylloglossum* *Selaginella* and *Isoetes* They are herbaceous plants growing close to the ground or as small epiphytes All are widely distributed except *Phylloglossum* which is confined to portions of Australia New Zealand and Tasmania The greatest number of species are to be found in the tropical zone although some species of *Lycopodium* may be found in the arctic regions Nearly all of the genera grow in moist shady habitats

Structure The living Lycopsida are characterized by a dominant independent (self sustaining) sporophyte which is differentiated into a root stem and leaves The stems and roots branch dichotomously (fork) The leaves are small simple and spirally arranged *See* LEAF (BOTANY) Typically they have but one vascular bundle which produces no leaf gap as it departs from the stele of the stem *See* STELE STEM (BOTANY) VASCULAR BUNDLES The vascular tissue of the stem is usually a protostele consisting of a solid central core of xylem surrounded by a cylinder of phloem although some lycopods have the center of the stele composed of parenchyma (pith) rather than tracheids an organization termed a siphonostele (*see* PARENCHYMA PHLOEM XYLEM) The phloem is surrounded by a pericycle and a well defined cortex and epidermis (*see* CORTEX PLANT EPIDERMIS PLANT PERICYCLE) The tracheid found in the vascular tissue are largely scalariform Several species have a cambium which forms secondary



g. 4. Isoet s tt ll n t l ze (F m A W pl Pl t M ph l gy M G w-H ll 1953)



D g am f lymph node (Afte C Toldt A Atlas of Human A tomy F Stude ts a d Physic ol 1 2d d M m ll 1941)

scular ti ue (see MERISTEM LATERAL) The spo-angia (por p od ing stru tures) re s l tary on the upper fac of fertile le es c lled sporo-ph lls. The po ophyll may be l calized at the tip of a branch and f rm a tru ture called cone or str bil s. The e is a te den y fo the sm ll g me-t phyte (gamete-p oducing generat n) to be apro-phytic (li ing o dead rga c matter) The sp rm p od ced in the anth idium re bifl gellate and motile. Se I OETALES LYCOPODIALES LYCOPODI EAE SELAGI ELLALES TRACHEOPHYTA [P.A] *Bibliog phy* H C. Bold *M phology f Pla ts* 19 7 H J *Fuller nd O T ppo Colleg Bot y* rev ed 19 4 A W Haupt *Plant Mo phology* 1953 G M Smith, *Crypt gam c Bot ny* v I 2, 2d ed., 1955

Lymph node

Aggreg ti of lympho d ti s e fo nd alo g the ou se of lymph tic e el Th y y n l gth f om 1 mm t 2 cm or mo e, a d n hape f om sphere) to fl tten d n n r m e sides A fi b a le urr d each gl d d e ds p-p rting she t be ul e through th lymph d tis. e Th lympho d tis u s c mp sed f g rm n l t f lymphocyte t g th w th the cells, parti l rly tho e f the r ti l e dothelial tem. Lymph glands r f d n s p fici l nd deep sit s, including th e k ax lla, g o med astinum, abd m pelvis, nd nte t l wall (Pey p hes) At l ast t f ti ns re pp e t to upply lymph t the c l ti n and to e mo e b cteria I t m tter carr d t the node by the lymph t c els. *In additi n it i* th ught that lymph gla ds m y be the ite of anti body f rm ti n *S e* ANTIBODY LYMPHATIC SYS-TEM [E.C ST]

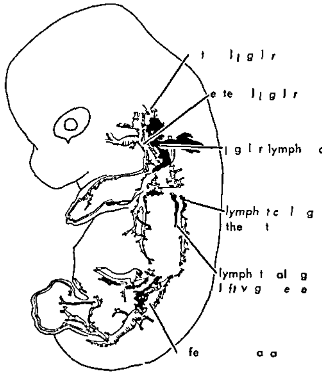
Lymphatic system

A system of ves els in the vertebrate body begin ning i a netwo k of exceedingly th n walled cap-illar es i alm t all the organs and tiss es exc pt the b in nd bones. This network is drained by larger hannels, mo tly cour ng lo g the eins and entu lly joi ng to f rm a large e el the th racic duct, wh ch run beside the spi l c lumn to enter the left subcla ian ein at the ba e f the ne k The lymph flu d rig nat s i the ti sue p c by filt ation from the blood capillaries While in the lymphat c capillar es it is cle r nd watery At i tervals, h we er long the larger lymphatic es-sels the lymph passe through pongelike lymph node wher it recei es great numbers of cells, the lymph cytes, and becomes turbid The lymphatic essel *other than capillaries co ta n numero s* al es p e enting back flow of the lymph The *function of the lymph tic syst m are to remo e* particulat materials such s molec lar proteins and bacteria from the tis ue to transp rt fat from the intest nes to the blood and to supply the blood with lymphocyte

Th s arti le conta ns sections n th embryology f the lymphatic system and spleen and the om par ti e n tomy histology and phy iol gy f th lymphatic sy tem

EMBRYOLOGY

The m de f d elopment f th vas ular system in c nt ad t nction to the arte i l nd ve o s sys-*tem ha b n lu d ted nly nc ab ut 1910* Emb y s f repr se tati pe ies f m ll cla s of rt b ate ha e been tud ed nd s y t th re s n gre m t n fu damental q esti ns pert n ng t th e ly embryol gy of th s el s y t m The n l d tatus ppe rs to re t m e n d ff nce of terp t i ons th n n n uffic e t ob rv tion d f ct



Fg 1 Lymphat c essels a d vei s n a 14 5 mm rabb t embryo (R O G eep d H st logy Bl k s ton–M Grow H ll 1954)

A harp di tinction must be made between the processes of the earlie t formation of di crete *lymph vessels and tho e leading merely to an ex*tension of once establi hed channel The former entail actual gene is of endothelium (va culogene sis) the latter merely repre ent gr wth Growth by budding and branching of ne ly e tablished ve sels occurs throughout the va cular sy tem whether hemal (arterial and venous) or lymphatic The controver ial a pects mainly concern the ear liest beginnings of lymph ves els

Theories There are two c nflicting concepts One is that all lymph channel develop by centrif ugal outgrowth from embryonic vein specifi ally *from their endothelial lining In the neck and loin* regions as well as in the po terior abdominal wall and at the root of the inte tinal me entery such outgrowths form saclike expan ions (Fig 1) These are respectively the jugular and iliac (lumbar) lymph acs *the future cisterna chyli* (pool of chyle near the base of the abdominal aorta) and the mesenteric lymph sac All the body pervading lymphatics are aid to be formed by prouting from the e sacs and thus to be derive l in directly from the lining epithelium of blood ves el The original points of budding from certain veins *(cardinals for* instance) either could be retained or lost and econdary evacuation taps for the lymph could be e tablished

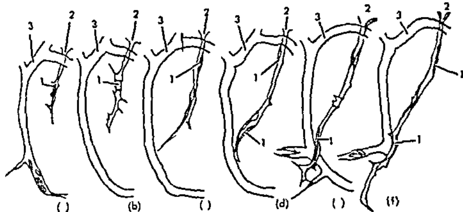
The oppo ing view holds that the lymphatics arise directly from me enchymal spaces either ad jacent to decadent *venules or* unassociated with veins During early embryonic development some rich and temporary venous plexu es become reor ganized Certain venules atrophy and disappear particularly in regions of the developing lymph acs The drainage function is taken over by a lymphatic netv ork which temporarily may carry blood cells received either from degenerative ven ules or fr m blo d i lands in the urrounding mes enchyme The ultimate connection with major *stem veins is always secondary The y tem ari e* in a di continuous manner and independently of the endothelium of veins The over all direction of its development is centripetal The i olated and di crete paces converge and fu e to form continuous lymphatic trunks and network The main connec tion of the jugular lymph sacs with the venous sys tem devel ps early *before the more di tal lym*phatic primordia have interconnected or joined the acs This link between two drainage sy tem lym phatic and venous occurs near the ba e of the neck (Fig 1) at the jugulosubclavian junction

Investigative methods *There* are tv o general methods for the investigation of lymphatic gene is each has erious limitation They con ist ei ther of the study of erial ections of well pre erved embryos or of injections of the de eloping lymphatics (Fig 2) Crucial events in that develop ment take place very early in human embryo for in tance *when they measure only 10 mm Obviou ly* it i impos ible to detect di continuous egment of developing lymphatics by the injection meth d Se rial ections on the other hand can be obtained of uninjected a well as of injected embryos This *method in it turn pre ents difficulties in regard to* fixation effect hrinkage of the delicate embryonic ti sues and interpretive errors in recon tructi n Further progre s may depend on newly devi ed methods

The late t evidence strongly supports the cen tripetal view of the origin of the lymphatic y tem According to this iew the very fir t beginnings are identical with tho e of the arterial and venous com ponents of the a cular sy tem All a culogene is appears to occur through the ame fundamental transformation of mesenchymal cells into end the lial cells The lymphatic precur or tage ucceed ing the de elopment of vein are as a rule le s dis tinct e anescent and therefore difficult to rec g nize This has cau ed differing interpretation

Embryonic phase In human embryos of about *1 in (20 30 mm) a connected primitive lymph y*tem is already e tablished The main lymph chan nel a cending through the thorax in front f the ertebral column (thoracic duct) has joined the jugular lymph ac At its distal end it is c ntinu ous *with the ci terna chyli into v hich c nverge the* lymphatics from the inte tinal tract and tho e of the lower trunk and limbs The jugular lymph sacs al o recei e lymphatic drainage from the de elop ing upper limbs through the primitive ulnar lym phatics *Other lymph trunks develop in the head* and neck regions o that the jugular lymph acs soon receive returning tis ue fluids fr m all body regions Lymph thereby is returned t the ec n my of the blood va cular y tem

In early tages *the thoracic ducts are paired and* symmetrically de el ped Some animal retain d u



(1) ucl f lymph l (2) lymph l (3) blood sel

Fig. 2. S ss t g ( )-(f) th g wth of a h (R O G p d H st l gy Bl k st n—M G w lymph t sel the t l f t dp le d g 72 H ll 1954)

bl thor cic ducts. In m y m mmal d m the tho c c d ct sy tem bec mes a yn m tri al thr gh th f rmat o f i terconne ti g li k a d tr phy f rtain segm ts H nc f tl l mph d ai g fr m th l r body reg s cc rs thro gh a si gle m in tr k whi h t m at at the l ft j gul bcl an ju ct n

Fetal phase Dur g rly f t l m nth the mai l mph tru k a w ll as the p ph ral lymph sels become pr d d w th l e wh ch ar se e rli in lymphat es l tha i v n Th ir struct l rr ng ment e ha s nt ip tal fl w f l mph By th fifth m th al e are prese t thr gh t the y tem (F g 3)

By gro th f e ti e ti u t a ds th lymph sa bec me tran f med to a l cy plexu or fenestrated tru t e l the m hes betwee the r mains g lymph sp s th me n hym l c ll p lif r t pidly Bl d cap ll s perv d th n bridge nd imm t re lympho yt ppear gre t n mb The h le p e e t th b gi



Fig 3 V l lymph l (C rt y G l

ning of a lymph node (F g 4) Tr e lymplocyte f rtl er nfli ate the t uctu e a d t r du e c mp t ell lar ma ur unded l y lymp l e sel Th mpl x m y bec m uld i ided t f m gr up f m ller lymph n de B the middle f fetal life tl e di g lymph el f rm cl ara ter t p phe l nu and an in e ting p le i f m d b the adj e t c ect e t The full diff e t at o of lymph node s ttai ed nly after b th

SPLEEN

Th i th large t l mph d t i r in rte- br te The so r e mat ial for the de l pm nt f th ple n i spl nch i (i er l) me de m n the d r l me e t ry f th embry c st m ch (do al me g trium) Th pl e arises in hum n embry s ab t 10 mm in l ngth s an nc n p cu thi ken ng n th l ft de f that s pen ory f ld f the t m ch A a r ult f r g la ell p l f r ti th tl k i g l c me n d la The b da betwe n the ing pitheli m a d th nd ly ng m e hym t often nd t nct he the pe fi tr but of e ch rem in n d bt The b e of th p lifer t g re g ow le ap dly a d ult mat ly be mes the ecti g fold b twe n the st ma h nd the ple n (g tro- pl l g me t)

B e th f lly d el ped sple n is nt r a l ted in the bl d t e m (filt ring bl od rather than lymph) t bec m pervaded by bl od pil l e e ly de el pme t The st m es els are th f tur sple c rt y nd ein

The d el pme t f f rthe tr ct ral d t ils i low B twee th th nd ighth week of hum n d l pme t (15– 4-mm emb y s) the pl en pr m d m is t ll m ely a densely p cked ma of ell lt ppr ches it typ l f rm d r g th thi d m th Th fi t o p c ter ellular p pp ar nd d fi te ell ds f r t c lar ell b g n t form a netw k N mer u fr ll l b twe n th me he Other ell a r g them el e c c t i ally r d the blood s ls

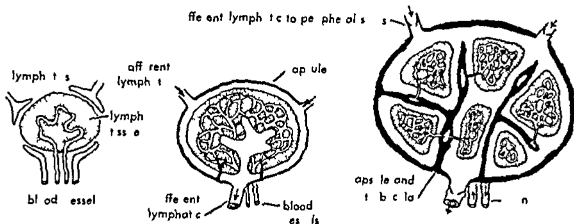


Fig 4 Development of a lymphatic gland (L B Arey and R L Rea Developmental Anatomy 6th ed Saunders 1954)

In the fourth and fifth fetal months the lymphoid cells appear and almost synchronously many pre cursor stages of future red blood cells appear This blood forming function is called erythropoie is It is temporary in human embryos but fairly con pic uous in the fifth and sixth fetal months During that time the meshes of the reticular background con tain many immature and mature erythrocytes (red pulp) Later the production of lymphoid elements predominates Gradually a white or lymphoid pulp develops Lymphocytes are being produced mainly in areas surrounding the specially shaped sheath (arteries with thickened walls) Full development of the white pulp with lymph follicles and germinal centers is protracted until after birth There are no lymphatic afferents to the spleen although the later developmental features of the spleen resemble those of lymph nodes Some forms of white blood cells are produced in the spleen throughout life and used up red blood cells are being continuously de stroyed in it [A A Z]

COMPARATIVE ANATOMY

Invertebrates It is disputable how far down in the animal series lymphoid tissue is found Some authors speak of lymphocytic cells in annelid worms in mollusks and in other invertebrates

In general the more primitive and le s differen tiated blood cells resemble more closely the lym phocytes of vertebrates This is true also of the lower chordates in which so called lymphocytes of the tunicates are said to differentiate into any of the other cell types of the body Lymph nodules are described in some species of tunicates in the body wall and in the gut wall

In the nonchordates it is difficult or impossible to make a distinction between blood vessels and lymphatic vessels Probably the two systems had a common type of origin

In *Amphioxus* how ver among the lower chor dates lymphatic vessels can be identified surround ing the blood vessels and are een also around the central nervous system in the dorsal fin and in the metapleural folds

The lymphatics of vertebrates are distributed in somewhat the same manner as are the veins (Fig 5) Thus they are divided into a deep and a super ficial set The deep et develops in relation to the cardinal veins and then makes connection with them and with the superficial set See LYMPH NODE

Fishes In fishes the lymphatic sy tem varies in degree of development in different species In some the veins seem to carry on the function of lymphatic drainage but in a number of pecies of ganoids teleosts and elasmobranchs a well devel oped lymphatic system is seen The lymphatic ves sels surround the veins in the elasmobranchs in other fishes they are not so closely related to the blood vessels In the elasmobranchs also there may be one or two large trunks which run parallel with the aorta and are comparable to the thoracic duct or ducts of man and other mammals Pulsating or gans called lymph hearts which assist in driving the lymph along the vessels occur in some fishes (Fig 6) The lymph vessels lack valves Lymph nodes are absent although there are collections of lymphoid tissue chiefly close to mucosal surfaces Nodules are found in these collections but they lack germinal centers

The organ of Leydig of the selachian fishes con sists of two large accumulations of lymphoid tissue which run longitudinally the whole length of the esophagus and even extend into the stomach Al though the cells of this organ are primarily lym phocytic they apparently serve as stem cells for all the types of white blood corpuscles in the e fi hes and hence the tissue perhaps should be spoken of as lymphomyeloid indicating its hematopoietic as well as lymphoid character See GLAND

In the sturgeon a mass of lymphoid tis ue has been described which occurs near the heart and resembles a lymph node but its homol gies are doubtful

Amphibia In the Amphibia the lymph sy tem often includes ery large subc tane u sinu probably to protect again t the danger of l of moisture Dilatations of the lymphatics or lymph sacs occur frequently Lymph hearts are c mm n

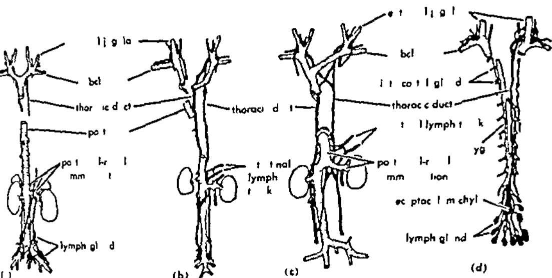


Fig 5. D g m ll t t g th ch f lymph t c tru ks d th l t t the m mm l V tral ws. ( ) So th Am c m key (b) M m- l (Lep s) wh h p t L l c mm c t o re t g ( ) Momm l g e l (d) Mo (po t co d kid ys t h w) l ll m mm l lymph ters th t th p t f j ct b twe the j g l o d th bcl s. In m t m mm l th l omm t b tw e the lymph sel d th p t l d ol s. In m th ght th c d ct d ge r t p rt d th ly c m- m ot w th e s t the o t f the jug l (H V N l d H W R d Cho date A t my Bl k st n—M G aw-H ll 1939)

m n us parts of th body nd a thor cic d ct s present. A cum l tio s of lympho d tissue a e f ten p esent dj c t to the lymph sacs but ar n t compar ble in archite tu e to the lymph nodes f higher rt b tes They may ho e er repre ent an early tage in the de el pme t f h n de

Reptiles. R ptil s h e well-de eloped lym phatic y t m b t la k the pec l features ee i amphibi ns. I the o diles tr e lymph node ha e b en describ d i the me e tery

B rds I the l mphatic system f b rds, lymph odes are w ll develop d in some spec e and h not been dem nst ted n the s They are defi nit ly p ent in ducks, both w ld and d m st c n gee e and in w ns The locati ns re the c n cal ers othora i and lumbar regi ns

The ar hite ture of lymph nodes of birds is sim ple th n in m mmal I b ds they ari e by dif ferent ti n with n the walls f lymph tic ve el wher a in mammals they ar e n th surr und g ti sue Th lymph id ti ue of birds c ntain l ght areas in the od les the s called germinal center whe e mit e oc ur These centers in bird how e er u ually r more abundant ne r the l rge si u occupy g th c ntral p rts of the node and sp ngy unorganiz d mass of lympho d ti s e ccupie the pe iphery In mamm ls the lymph id nod le with their germinal center l e in the per ph al eg o In both b rds and mamm l the germinal ent r how n t only m totic figu es but al o m ny lymph cytes n proc ss of degene ation and l rge ph go yt c cells wh ch ta n fragme t of lymphocyte or whole lymphocyte within their cytoplasm

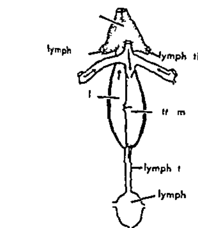


Fig 6 Ly ph h rt t l f t l t (G C K t C p l A my f th V rt b t Bl k st n— McG -Hill 19

Mammals Th lymph n des of mammals ary numbe s z form a d truct re in diffe nt pec s Ther appea to be ome rath r surp i ing d ffe n e n numbe f lymph n de in d ffer nt ki d f m mmals F ex mple, th dog s s id to h e ab t 60 the cow 300 man 465 and the h r e 8000 I th dog nd c w howe r th lymph node a e el t ly la ge in m n nd the hor e they lat ely m ll Their h p lso vari s l the w fo in ta e the m e ter c nod s e l g nd arr w tta n g l gth of e al de mete In the bbit th me. nter n des e m to h l d to n huge nod th pa re s a ell w gh g r l tim as much as ll the the n de c mb ed Th re a s m lar r a ge-

ment for the mesenteric nodes in some other ro dents and in some carnivore The e pecie include the mole the dolphin the eal and the narwhal whale

The amount of connective tissue of the lymph node that is the degree of development of the capsule and trabeculae varies in different mam mals It is weakly developed in the *pig dog heep* rabbit guinea pig and rat *In man and in the horse* the trabeculae of the medullary part are more strongly developed than those of the cortex Many mammals show a strong development *of smooth* muscle in the capsule and trabeculae as in the hor e sheep cow and dog The cow *has an espe*cially thick capsule and trabeculae

In some lymph nodes the cortex with its nodules is *very sharply set off from the medulla with its* more diffuse lymphoid tissue *This is true of the* cow In other animals the nodes seem to vary in this respect in different parts of the body or even in a rather haphazard manner whereas in still oth ers such as the pig there may seem to be almost a reversal of arrangement with the nodular tis ue *situated centrally and the diffu e tissue peripher* ally

Other lymphoid organs These include the ton sils thymus *gland and pleen and in* certain classes and groups of animals structures which are confined to such groups for instance the bur a of Fabricius in the birds *a diverticulum from the* lower end of the alimentary canal *See* SPLEEN THYMUS GLAND TONSIL

Tonsils The tonsils seem to be represented in the frog and toad by two large fossae palatinae invagi nations of epithelium surrounded by dense masses of lymphoid tissue Smaller structures of simple construction al o are pre ent

In the posterior part of the buccal cavity of *Proteus and Salamandra* there are areas in which the *epithelium is thickly infiltrated* by lympho cytes

Among the reptiles *Lacerta agilis* shows defi *nite tonsils in the pharynx* with *elongated* lymph nodules occurring along epithelial invaginations and with an apparent lack of basement membrane and a complete intermingling of epithelial and lymphoid tissue near the surface Tonsil are seen *also in the crocodiles*

Birds not only have large aggregations of lymph oid tissue in the pharynx but often also a large esophageal *tonsil The light* taining germinal cen ters are een for the first time in birds

A ring of lymphoid tissue known as Waldeyer s ring con i ting of palatine pharyngeal and lin gual tonsils is pre ent in many mammals as in man but other mammals may lack one or more of its component parts In the rat and mouse there are no palatine tonsils In the hare and rabbit pha ryngeal ton ils are lacking The rabbit hare dog cat and heep apparently lack lingual ton ils

Tonsils of the hor e are peculiar in that they contain structures apparently identical with the Hassall corpu cles of the thymus gland

Spleen The spleen is an organ of dual nature *belonging to both* the blood va cular and the lym phatic system In the lower vertebrates it i actu ally within the wall of the alimentary canal In cy *clo tomes* it lies in the submuco a of tomach and *intestine In the* lamprey it is within the spiral valve Among the Dipnoi it is found within the *stomach wall* but in ela mobranchs and ganoids it *is a separate* stru ture attached to the me entery In fishes and amphibians it is active as an erythro cytopoietic and lymphocytopoietic organ Its func *tion of forming lymphocytes* is important al o in higher vertebrates (including man and other mam *mals) but its blood cell forming function* is lo t and *replaced by one of de truction of* old or worn out red corpuscles and to some degree of blood tor age *See* HEMATOPOIESIS

The lymphoid tissue of the spleen in higher vertebrates contains many nodules known as Mal pighian bodie These usually contain active ger *minal centers*

HISTOLOGY

Lymphoid tissue is a tissue in which the pre dominant cell type under normal conditions is the lymphocyte Lymphocytes are as ociated with re ticular fibroblasts which form a delicate framework *of fibers which can be* demon trated by their affinity for ilver There usually are cells of other types present al o including macrophages (fixed *and free)* pla ma cells and occa ional eo inophilic granulocyte

Function The chief function of the lymphoid *tissue is to produce lymphocyte In efferent lym phatic vessels those leaving* the lymph node lymphocytes are considerably more abundant than *in afferent* lymphatics Lymphocytes are added to the lymph as it flows through the lymph node The lymphocyte content of veins coming from the node al o is greater than that of arteries g ing to them *Apparently ne ly formed lymphocytes* al o migrate into the capillaries and mall veins A econd im portant function of lymphoid ti sue is protection against infection which it carries out by means of its phagocytic and antibody produ ing activity

Cellular composition Lymphocytes are of dif ferent size small medium and large The range in ize of the e three kinds however varie with different classes and even species of animal The large lymphocyte re emble very cl ely the tem cell of blood forming ti ue the hemocytobla t In fact lymphoid ti sue itself bears a c n iderable resemblance to hematopoietic ti ue and in lower vertebrates it is not alway possible to di tingui h ne from the other

The function of the lymphocyte them el i imperfectly known The tudy f c mparati e hi tology however eems to throw light on their probable role in higher f rms In many in e t brate the regenerati e p wer are mi h gr ater than in higher vertebrate It ha been hown that primiti e mesenchymat us and free lymph id ell often aggregate to form the variou organ pri

m rdia and e e t lly e en a c mpletely d ff ent ted s m l In some fl tw rms t has been f und that not only do new parts ri e f m u h lem t (ell th picuo s nucl oli a d b ophili cyt plasm compar ble t the large lym phocyte) b t that the relat power f regenera t n in d ff e t peci s may be correlated with *th r latı e numbe s f su h cells* Thus whe e tl ey are um ro s, as in *Pla a ia* r gener ti e power high. When th y are not so omm n as i *Procotyla* reg erat e po i low In flat rm tl e e ell ill f rm s h aried *tructur s as epith lium of* the gut, germ cell and bra

Altho gh the lymphocytes of m mmals d not h e h remark ble pote tial t es many workers ha e ho n that they an de elop into ri u th types of cells, clud ng macr phages which are larg ph gocytic cell some type f granular hu lls f the blood red blood ells and fib obla.ts, fib r f rm g cells The gge t *has been m de also that they may metam ph e* into p thel al ells in some locat ns. Th s e of *their mportant les n the highe v tebr te is* still r g n ti e r ell r pla g o e

Lymph vessels The lymph ap llari s the smallest lymph e els, form a d n e n tw k in almost e ery porti n f the body They appear to e d bl dly d co si t nly of n e d thel al l yer As th y u t t f rm l ger v els connect e tis. pp ar i the all Th bl d r nded end f lymphat c c pilla e re ly seen in the lacteal n th illi wh ch re i e the fatty f d fr m th testin l lumen a d he c c ntai n hyle, fluid m de milky by the p e ence f multitude of mi t dr plets of fat (F g. 7)

l larg r lymph tic s el th re are m re c l lagen fibe s and lso som el st c and mo th muscle fiber In v el with a diameter f m re th n 0 ? mm th w ll ge e ally h w three layer wh ch b r the same names as th e in the blood e els, namely intima m dia and ad entitia In lymph ve ls the ad entit a i u *ually tl e thick t* layer and often contain mooth m scle cells as well as c ll g n us and ela tic c ct e ti sue fibers In the large t lymphatic e el the r ght lymphat c d t a d the th aci du t th med i more fully devel ped nd contain con derable mooth m scle

Lymph nodes The lymph nodes are m sses of lymph d ti sue with a pecial type of rch tecture. They are i t rp sed s way t ti ns in tl e cou se of the lymph tic tre m The e sel nter ng the n de re alled affer t tho e lea ing it re the effe e t e el

The c tex u lly co i t of rather den e lym phoid ti e mp sed of r u ded nodules, made up h fly f mall lymphocyt In the ent s f *the nod le are l ghter tai ing po ti the ger* m nal ce ters with m cr phages nd lymphocytes *of med um a d l rge ze frequently seen in* mit s.

Th medulla of the lymph node con i t f na tomosi g chan el r sinusoid thr gh which the lymph is our ing t ward the effe ent ve s ls a d f c rd of lympho d t e It i mo e po gy th the cort x

The lymph nod i su r unded by a c p ule con ist ng f collagen us and ela tic c nnecti e t ue fiber and ften ontai ing me mooth muscl At th hilum where the blood v ls f the *node ent r nd lea e nd fr m wh ch the ffer nt* lymph t c emerge th c n ecti ti sue f the c p ul p net ates well into the n d

Fig 7 Cro sect f d od m (T f St d *R. L. U* g G 1 2 *l gy 3d d M G w-H ll* 1957)

PHYSIOLOGY

Lymph formation In ny gi en egion th fluid wh ch enter lymphat c ap llary may be that wh ch i lo e t the arte i lar or t th e u nd f a bl od c pill ry r t may b flu d rel t ely d st nt fr m e the Th r e ists a grad e t of p s u f m the t s ue fl d t the lum n f the lymph t c c p llary In edema s ch a be b ught abo t e periment lly by tre tme t w th yl l r by h at th gradie t is increa ed Th s p es- ur gr d nt i a importa t fa t i th f rm t n f lymph *S e E* FMA

A y fl d n wh ch filtr t e c ed ab rpt on th gh th wall f the bl d p ll ry is n rmally dr i d by the lymphat Expe imentally this s *h w wh filt t n te s* cre s d by nt e t an f s n by wa m ng f p rt

Function of the lymphatics The fu cti n of the lymph t s s t r m s ch cess fluid a d lso t turn to the *blood* tre m the pr te wh h has e ped fr m the blood p ll r es Lymph ll cted f m lymph ti s of the k d ey l g nd ri c l g n s w ll f m th th r d t, ha been hown t t n thi prot in wh ch h b en l k d f om th blood c la y tem The e p te i cl d erum gl bul um albumi

and fibrinogen The filtrate from the blood capillaries consists of water and of sugar and salts in concentrations found within the blood stream plus these proteins in low concentration The salts and much of the water are reabsorbed by blood vessels whereas the protein together with some water and salt enters the lymphatics When the normal drainage of protein from the tissue spaces is prevented elephantiasis may result as when the lymphatics are obstructed in filariasis The result is massive edema of a part with dilatation and thickening of the lymphatic capillaries and an overgrowth of connective tissue See FILARIASIS

In addition to water ions small molecules and the large molecules of extravascular protein particles such as injected graphite or extravasated red cells also enter the lymphatic capillaries Such relatively huge structures pass between the cells

Composition and properties of lymph Basically the composition of lymph closely resembles that of the plasma Chemical and electrophoretic studies show that lymph contains all of the types of protein found in plasma but in lower concentration The composition of lymph varies to some extent from one part of the body to another Thus the lymph from the liver contains more protein than that from the skin

The ability of lymph to coagulate depends largely on its content of fibrinogen and prothrombin and this varies rather markedly In dogs the mean prothrombin level is 7 6 for leg lymph 51 2 for thoracic duct lymph and 93 2 for liver lymph There are no blood platelets in lymph and it is thought that thromboplastin generally considered necessary in clotting is formed at the time of clotting from precursors present in the lymph Calcium also needed in clotting is present in the lymph in slightly lower concentration than in the blood

The ionic content of lymph does not vary much from that of plasma (Table 1) Chloride and bicarbonate levels are higher in the lymph than in the plasma whereas total base is slightly lower

The glucose content usually is essentially the same in the lymph as in the blood Curiously the lymph of the kidney has a lower concentration of glucose When carbohydrate is fed or when an intravenous injection of glucose is made the concentration of this sugar in the lymph lags behind that in the plasma but eventually catches up when an equilibrium between plasma and lymph is attained Concentrations of amino acid creatinine and urea are approximately equal in lymph and plasma but in the kidney the urea of the lymph is slightly higher than that of the plasma It seems probable that some of the renal lymph comes from fluid reabsorbed from the distal and collecting tubules See KIDNEY URINARY SYSTEM

The lipids consist of neutral fat forming the chylomicrons and of cholesterol and phospholipid the latter two kinds of compounds being associated

Table 1 Average values for the concentrations of electrolytes in lymph and plasma

Substance or property	Source of lymph	Subject	Plasma	Lymph	Anesthetic
Sodium meq/liter	Thoracic duct	Man (5)	1[illegible]7	1[illegible]7	
	Cervical duct	Do	163	157	Nembutal
Potassium meq/liter	Thoracic duct[b]	Man (5)	[illegible] 0	[illegible] 7	
	Right lymph duct[d]	Dog ([illegible])		5 [illegible]	Nembutal
Calcium meq/liter	Thoracic duct[b]	Man (5)	5 0	4 2	
	Thoracic duct	Dog (1)	5	4 6	Amytal
	Cervical duct[f]	Dog (11)	5 8	4 9	Nembutal
Chloride meq/liter	Thoracic duct[b]	Man (5)	[illegible]6	98	
	Thoracic duct	Dog (1)	110	116	Amytal
	Cervical duct[f]	Dog ( )	116	1[illegible]	Nembutal
Inorganic phosphorus mg%	Thoracic duct[b]	Man (5)	4 5	4 4	
	Thoracic duct	Dog (1)	4 3	3 6	Amytal
	Cervical duct[f]	Dog (3)	5 6	5 9	Nembutal
Carbon dioxide ml%	Cervical duct	Dog (7)	56 8	58 8	Nembutal
Carbon dioxide tension mm Hg	Cervical duct	Dog (7)	46 4	40 3	Nembutal
pH	Cervical duct	Dog (7)	7 34	7 41	Nembutal

Numbers in parentheses indicate number of subjects studied

[b] H R Bierman et al The characteristics of thoracic lymph duct in man J Clin Invest 3[illegible] 637 6[illegible]9 19[illegible]3

O H Lowry and F W Maurer quoted by C K Drinker and J M Yoffey Lymphatics Lymph and Lymphoid Tissue Harvard University Press 1941

[d] F C Courtice unpublished data

R M Arnold and L B Mendel Interrelationships between the chemical composition of the blood and the lymph of the dog J Biol Chem 7[illegible] 189 [illegible]11 1927

[f] J W Heim On the chemical composition of lymph from subcutaneous vessels Am J Physiol 103 [illegible]3 558 1933

J W Heim and O C Leigh The carbon dioxide content and combining power and pH of cervical lymph Am J Physiol 11[illegible] 6[illegible]9 [illegible]04 193[illegible]

briefly with potentials to form lipoprotein. The qu tity f n tral fat d p nd n th f t ab p- t by th l t al f tl e inte tin and tl e am u ts f h lester l nd ph l lip d ary with the am unts f pr t p e nt

Lymph flow Co t act lity f tl e walls f lym ph t es l m a d th r m mm ls p e rs to be nly l ght a d t play a mi r r le n lymph fl Th s in mark d ntr t t tl e d t n in so e lo er erteb te part ula ly the ampl b a m h h ll-de l ped p l atile lymph heart c ur l g th r e of the lymphat c cl n els (Fig. 6) Th lymph fl w in mam l ls ppears t be ry l g l mp d with tl at in tl f r g The th r l w r t of fl w f the lymph n dog e T ble 2. It l ul ted that e tr a ular ul t i ol 50–100% f the pl m p o- t h d y (Table 2)

The p e f th lympl fl w ri ble e n ma g e lymph t e l Becau e l mpl fl w tr petally it i lear that th peripl e al lymph d r high r pr re th th t f rth r l ng the essel M cle nt t n uch as th e f tl e l g in lk g may g tly re se the pre ur f the lymph i di d l r gi D ing c tr t f th m le the lymph t s t d t empty h as d ri g el t tl y fill ag I e e pe ime t p e w re ded fr m a lym ph t j t bel w the popl t l lymph n de of d g h n th mal s t t b t d g r p d fl xi d te o f the l g th p e e 1 68 m f ter

M em t f lymph pr re ually a de d t d rd d t n f t P e e m j d f th tl d t f th d ha bee d d s 6 4 m f wate mpa d w th a pressur f 2.4 m i th t rn l jug la n f th me d g S h a p d ff e pro- m tes fl w f m the th d t t th u system

P e ures h bee rec d d f m a n mbe f diff e t lymph u l Th t of th lymphatic

Table 2. A g flow d p ot ont t f lymph f om ou lymph d cts i dog d mb tal th i

Lymph d ct†	Lymph fl w ml h	g%	Lymph prot g d y	Lymph prot % f t t l ant sc l pla m prot
Thora d t (4)	6 0	4 1	6 1	4 5
Right l mph d t (1)	3	3 7	0	3 6
Cer l d ts (18)		8	1 3	4
Forel g d ts ( )	3 8	1 3	)	
Hindleg d ts (17)		1 8	1 0	1 8

From C K D k d J M Y ff y Lymph tic L ph d Lympl d Tis e, d ed II d Uni rs ty Press, 19 6 A g w ght f h nim l h gro p as ppro m tely l kg d t sc l plas prote g T tal lymph p from l g d cer l d ts l des both des † N mbers p re theses p es t th umbe f als g up

apillar s is rather h gh h vi g been re orded 42 6 cm f water (31 3 mm f Hg) in the capillary of the llu

Lymphatic system in immunity The lymph n des erve a filte ing out pla es f r f reig par t l i cl d g microorg ni m bec use the lymph mes i t intim te ntact with the many phago yt c cells f the i u ids. Th e macro- phage are f both tl e f xed nd fr e wa d ri g type S e PHAGOCYTOSIS

In additi n to the pl ag cytic fu ct n e peri me tal t di f a e dem trated that lympho d ti e p d e antil d es If ant gen ucl s typh id bac lli r h ep erythr ytes are injected into th p d f the f t f a e per me t l an m l nt b die begin t app ar in the effere t lymph es el of th popliteal node a few days lat r a d their t t r p dly nc ase t a ma m m a d tl n de li S m i e t gat r ha e f und th t m t f th a tibody is within the lymph ytes rather th i tl e flu d The lympl n de how an inc a e i e of it ge min l c nte s a d there is in cre ed utput f lympl cyt s S e ANTIBODY

The a tu l p e of t body f rmat n i lymph d t u is t well u derst d A n d r ble body of e id ce wo ld a ign the chief l to the pl ma cell ge erally abund t in lympl d ti e rather th n t the lympl ocyt Ant gen inj ti h bee h wn t b g ab t t n pl ma ell p se i m ny in t ces Tl e e t of fluo e t a t g ns d ant b d ffe ev dence tl t ant g n fixed by pla ma c ll lymph odes which are f rming a t b d e b t ot fi ed by lympl ocyt The i re ed mb f lymph yt s in nfecti a d th i pas ge t th bl d t m m y th s ha me gn fi an e not nne t d with antibody f r m t n

Cerebrospinal fluid Th ereb pin l fl d fills th t i l s f th brain d the p between th ar hn d m t d the p mate Cerebro- p al flu d a l a l q id d ed from the c p lla y e l f the l r id pl which p m t tl e pa ge f w ter l tr lyt nd m ll m l cul s, but h ld b k the p t ns of the bl d Fl d p ng thr gh the w ll f th capillaries m t al g th gh l yer of ep thel m er g th p ll e T f protein are f u d n the m l c b p l fluid S e NERVOUS SYSTEM

By f the g ater p rt f th rebr pinal fl d ab b d t the f th ra h d ll Th lat h p betwe th reb pi l fl d d the l mph tic y t m f di certai g s wh h th fl id e c p s f m th m ges d te lymph tic p ll s. Th t m y p s by way f the a h d h th of th lfa t y erves t th bm f th na al c ty d ach tl erv l lymph tic essels. Arachn d er gs f the ry gangl l a e loc t wh b p n l fl d m y h th lymphat n th m l an m l

Cl lly ch con e tion m y e te by wh ch b t c ent the e t al

nervous system They may also in ca es of menin gitis or of hemorrhage help to clear the cerebro pinal fluid of cells and of pla ma protein

Cerebro pinal fluid differs from other lymph in its low protein content low cell content and lower pecific gravity (1 004–1 008) It contains no fibrinogen

The cerebrospinal fluid has at lea t three func tions (1) it acts as a fluid buffer against shocks and jars of the central nervous sy tem (2) it serves as a reservoir in regulation of the cranial contents and (3) it acts as a mechani m for ex change of ga es and nutrients in the nervous system In relation to the e functions its properties are particular but it may be considered as a specialized type of lymph [W A W]

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Lymphocytic choriomeningitis

A viral infection endemic in mice but occasionally transmitted to man in whom *it may produce a mild* influenzalike disea e or an aseptic meningitis Sometimes encephalitis or even a fatal sy temic di ea e may be produced

Diagnosis of lymphocytic choriomeningitis (LCM) is by i olation of the virus from acute pha e spinal fluid or blood or by increases in erum anti *bodies*

Mice are the usual reservoir of virus they may harbor it throughout life and transmit it to their offspring Dust and food contaminated by urine or feces are probable vehicles of transmi sion to man however *Trichinella spiralis* can be infected ex perimentally and has been sugge ted a a po sible means of transmission from animal to animal or through pigs to man [J L M]

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Lymphogranuloma venereum

A venereal disea e cau ed by a viru of the psitta co is group The infectious agent has been related to the lymphogranuloma p ittacosis group by struc ture de elopment forms staining growth in the yolk sac and antigenic components The di ea e, al o known as climatic bubo is manife ted in con stitutional symptoms and acute or chronic ti ue change in the inguinal and recto anal region

After venereal exposure painle s ve icles de velop on the genital organs or anus The infection may terminate here or it may progres to adenitis of the pelvic lymph nodes accompanied by fever and generalized ympt ms even pneumonitis In the chronic tage plastic induration of the male genitalia or in the female vaginal and rectal tric *ture with fistula* are typical

Elementary bodies may be een in cells from hu man lesions and they are transferable to the white mouse by intracerebral inoculation Pa t or pre ent infection can be detected with complement fix ation te ts or more commonly by the intradermal Frei te t Subjective clinical and functional im provement has followed treatment with the anti biotic terramycin In the United States the di ea e is more prevalent among Negroes than Cauca ians Serum surveys early diagnosis and treatment u pervision of infected persons and public e luca tion are important in prevention See ANTIBIOTIC ANTIGEN LYMPHOGRANULOMA PSITTACOSIS GROUP PSITTACOSIS SKIN TEST VIRUS

[K F M E]

Lymphogranuloma psittacosis group

Viruses of psittacosis ornithosis lymphogranuloma venereum certain localized infections of mammals *and inclu ion blennorrhea* mea uring 350–500 mμ in diameter compri e this group that lies along an indi tinct line dividing rickett ia from viru es They stain with formol methylene blue or other ba o philic dyes All grow well in the embryonated egg and tissue culture One heat stable antigen is shared *by all members* and the heat labile antigens are specific for individual members Many produce tox ins The e viruses are i olated mainly by inocula tion of mice or guinea pigs The tissue and cellular tropisms vary considerably within the group They are each usceptible to antimicrobial drugs to a omewhat different degree S e ANTIGEN CULTURE EMBRYONATED EGG CULTURE TISSUE RICKETT SIALES VIRUS [K F M E]

Lynx

Any of e eral moderate ized cat f the genus *Lynx* family Felidae chara terized by l ng leg short tails tufts of hair on each ch ek and tuft d pointed ears They are found in the Northern Hem i phere and Africa Although the b bcat i al o a lynx in the United States the name is i ually ap plied only to *Lynx canadensis* The lynx is about 3 ft long with a sh rt black tipped tail and large feet It occurs from Alaska acro s mo t of f re ted Canada northern New Englan l n rthern Michigan and outhward in the m intain into C l ra l

The lynx is a cat f the undi turl d f re t and eldom ha much nta t with man It i in pal food is the nowshoe rabbit r varying hare



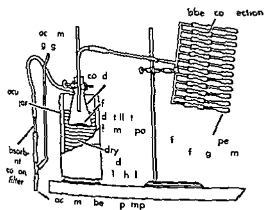
The lynx, *Ly od* l gth 3 ft *(F m E L. Fl er Fieldb k f N I l Hst y M G aw-H ll* 1949)

and th *numb r f lynx l ely follow the y lic* ab d ce of th ha e. *S* BOBCAT CAR IVORA CAT [J D B]

Lyophilization

Dry g n a uum f om the fr zen t te Wat r is removed by *blim tion f om the f e material* and th sol te i left s p ou lid The l t is se led in uo ft d ying d et i it b l gi al *it ib tes f r lo g p i d (ee llu tr* tion) When eco t tutio i de red th p p od ct r dily e dm t the dded sol nt l nce the app opriatene f the term ly phile. r l e t l g.

Appar t s f ly philizat o co i t f tain f th *fr zen mat rial t be dried* on nected t a manif ld wh h n ey the w t p r to a nd ng chamber the wh le appa at s evacu ted. Co d i *f th water ap m y* be by f eezing. mb t o w th a hem l d i



Appa tu f p d h gh- m d t f f be sions of b log m t l *(Aft St d R dg er A J S ll f d m t l P pl f B t l ogy 4 h ed M G w H ll* 1954)

cant r e acu t n by p u g (ee illu trati n) In de ic t n f la ge m t f material it is ad antageou to p ly h t carefully t ha ten porati n a dryi g p r c d

In elab ration of the p ri iple myriad f ri f pp r tu ha e l en m de r ging in capacity fr m ll l b rat ry e uip t tal le f r p erving v ble lt re f mi r g r ther lls nd ti ue t l b rate de i t f r plant le pre ervati n f erum p l ma antibi ti s horm e b ea t milk nd fo d tuff *S e* MICRO-BIOLOGICAL METHOD [M]

B bl og aphy E. W Fl d rf *Fr Dry g (D y g by Sublim t o)* 1949 R J C. Harri (ed) *B l g l Appl tions f Fr e ing d Dry ng* 1954

Lyra

The Lyre a.tronomy is a mmer n tellat on m ll b t imp rt nt Lyr has a fir t m gnit de tar Veg a na igat nal t and the m t br l ha t i in th p rt of the ky Vega form with two faint t to the ea t n almo t perf ct q i lat al tri gl The southern ne n turn f rms *w th thr b ight tar t the south n appro i* mate p all l g am The r lting er ll figur emble a tort e mor than tr nged mu al *n t ent How er rd ng t l gend* Mercury mad the fi t lyr f m turtle h ll by plac ng tr g a o t Hen e the tw differe t r p e en *tat n are t in mpat ble In thi con tellati n* l the famou R g Nebul *See* CONSTELLATION NEBULAE, GASEOUS [C S Y]

Lysin

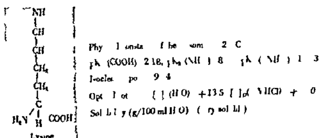
A term u ed n bi logy to de ibe sub ta ce th t *will di pt a ll w th th rel a e f ome of its* n tit e t U le the damage s mi or th c t le ds t the d ath f the cell Ly s ry in *the a ge f h t pe es wh o e ell they will t* t ck d n their eq m nt f r ces ry fac t rs f ly th immu ly n are t i te t n *ther q rem ts E yth o yt s e lysed by* w de i ty f hem al in lud ng w ter nd hy p rt n s lt l ti n whi h d plac the mot c *p e u fr m th t of ot n ty Th y a e* lso us-ept bl t fa e act b t n e such a po-n n M ny bact r a u h as the t phyl co c s *d the t ept c s el b ate o or m re* hemo-ly th t w ll ly e rythr cytes fr m rt i al tho gh n t all pec f nimals Th e p tt rns *m y b u d n th t o m c cl s fi t on f mi o g m* Th e r a numbe f ther lyti b ta ch ly zyme n ym in the ey q h m r nd t *me e te t* the b cte o-pl ge wh cl att k di r p c f b cte ia b t th e t ns a e t nt ly n pe fi s e they d p d th p e c *of mmo c ll* t i nt r cept r wh h d ot h we e d w th th l ed i mm ly *S e* BACTERIO HAGE STAPH LOCOCCI S *STREPTOCOC* CUS

Immune lysins This is a term used in serology to designate an antibody that in the pre ence of complement and cofactors such as Mg (mag nesium ion) and Ca^{++} (calcium ion) will di rupt a particular type of cell with the release of some of its constituents This action is in accord with the principles of serologic specificity and is to be dis tingui hed from the more general actions of other lytic chemicals Immune ly ins are al o classified according to the general cla s of cell attacked hemoly ins are antibodies lysing erythrocytes while bacteriolysins cause the ly is of bacterial cells Hemolysins against various foreign eryth rocytes occur normally in many era the Forss man and other heterophile antibodies and the blood group isoantibodies constitute special in stances High titers of hemolysins may also be pro- duced by immunization with erythrocytes and rabbit antibody against sheep erythrocytes is an im portant laboratory reagent the so called ambocep tor in complement fixation tests For example sheep erythrocytes injected into a rabbit produce antibodies in the rabbit against the sheep red blood cells The lysis of erythrocytes releases hemoglobin which may be quantitated by eye or by a color imeter See ANTIBODY ANTIGEN COMPLEMENT (SERUM) COMPLEMENT FIXATION TEST HEMO GLOBIN HETEROPHILE ANTIGEN LYTIC REACTION

Pfeiffer reaction This i an example of a bacte riolytic reaction carried out with gram negative bacteria such as cholera vibrios which are e pe cially susceptible to the lytic action of specific antibody complement Mg and Ca This reac tion may be carried out in vivo (Pfeiffer s sy tem) or in vitro and is a valuable aid in diagnosis An analogous reaction is given by the spirochetes of relapsing fever Although demonstrable in tances of bacterioly is occur it is not clear whether all the bactericidal actions of antibody and complement are necessarily preceded by ly is See CHOLERA VIBRIO [H P T]

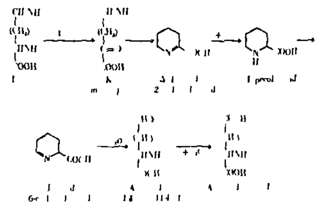
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Lysine



An amino acid con idered es ential for normal growth of animals The amino acids are character ized physically by the following (1) the pK_1 (r the dissociation constant of the various titratable groups (2) the isoelectric point or pH at which a dipolar ion does not migrate in an electric field (3) the optical rotation or the rotation imparted to a beam of plane polarized light (frequently the D line of the sodium pectrum) pa ing through 1 decimeter of a olution of 100 grams in 100 ml (4) olubility See EQUILIBRIUM IONIC I OELEC TRIC POINT OPTICAL ACTIVITY SPECTROPHOTOMET RIC ANALYSIS

Lysine is a precur or of biocytin (ε N biotinyl L lysine) and of 5 hydroxyly ine which occurs only in collagen a pecial protein Lysine bio ynthe is is of particular interest becau e it is a phylogenetic property which together with other feature sets the bacteria and blue green algae apart from all higher microorganisms plant and animals In the former group ly ine originates by decarboxylation of diaminopimelic acid (*see* AMINO ACID) In higher forms ly ine is formed by way of α keto- adipic acid a product of α ketoglutarate and ace tate During metabolic degradation it has been well e tabli hed that the following equence take place lysine → α aminoadipic acid → α ketoadipic acid → glutaric acid → α hydroxyglutarate → α ke- toglutarate The conversion of lysine to α aminoad ipate requires a complex series of reactions in cluding an intramolecular tran aminati n there i considerable evidence for the following



See TRANSAMINATION [E A AD]

Lyssacinosa

An order of the ul cla Hexa ter phora in the class Hexactinellida In the e p nges the paren chymal megasclere are typically fr e and unco n nected but are metime econdarily united The parenchymal megascleres vary from hexactin to diactin the latter are alw ay pre ent and me time exclu ively) *Is onema Eupl ct lla Ros sella* and *Rhabdocalyptus* are example f this rder See HEXACTINELLIDA HEXASTEROPHORA [W D H]

Lytic reaction

A term u ed in erology to de cril e a reacti n that leads to the di ruption or ly is f a ell The be t example i the ly is of heep red blo d ell ly ie ific antil ody ly in ard c mpl ment in the pre ence of Ca (calcium ion) nd Mg (mag ne ium i n) a reaction that f rms the indi at r

tem of the st d rd Wa rmann test for syph ilis as ll ther c mplement fi at n re ctions. I thi example ly is result in the release of cel l lar h m gl b t t *the medium the re ction* m y b f ll ed by i ual r in-trum nt l e-tima ti f the decrea ed ll turbidity r the increa ed l of the med um d e t the free hemogl bin By appr p te cho e f graph p pers and coordi tes th entire se f h moly is r a range of reagent c n entrat ns may be predi ted fr m tw or m re accur te mea urements in the intermedi ate range As outlined by M M Mayer nd his *associates the mechani m of the lytic react on of* red cells is a mplex multi tepped ne

[H P T]

B bl g aphy M M Mayer Studies on the mechan m of hem lys s by antibody and complement *Prog in Allergy* 5 215 1958